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EDITORIALS

Farm Practice Research

IT is almost self-evident that the best customers of the farm equipment industry are those who achieve enough balance and overall success in their farming operations to be good repeat and replacement customers, and living examples to their neighbors of the advantages of farming with good equipment.

Farmers and the farm equipment industry have a mutual interest in the financial or material success of farming. Increased recognition of this mutual interest may be indicated by the recent creation of a division of farm practice research in the organization of one full-line manufacturer. In fact, this development might well set a new pattern for the industry in its work of rendering an economic service to farmers. It marks acceptance by the manufacturer of increased responsibility for customer satisfaction with its products.

Farm equipment has been well-engineered from the standpoints of mechanical design, efficiency, durability, dependability, adaptability, and economy of manufacture and service. But even the best equipment can be used so little or so poorly that the farmer would be better off without it. What a division of farm practice research, or comparable setup, can do is to carry the excellent engineering of equipment to its logical conclusion in the engineering of equipment use. Farmers need engineering help to make the most of the mechanical capacity, adaptability, and serviceability built into their equipment.

Farm equipment is mostly production equipment. Its use is subject to engineering refinement in analyzing the jobs to be done, matching equipment types and sizes to job requirements, and operating the equipment efficiently.

In terms of fundamentals, jobs to be done by mechanical farm equipment are principally the physical manipulation and transportation of materials as aids to biological production, and to the harvesting, preparation, utilization, and marketing of biological products. New information on physical factors in crop and livestock production; new crops and crop varieties, market grades, uses, market demands, sanitary requirements, and transportation conditions frequently change the jobs to be done by farm equipment in important details. Changes in jobs to be done change requirements of equipment design and operation. Frequent analysis and reanalysis of jobs to be done by farm equipment is the first requirement of an engineering approach to improved and increased farm equipment use.

Matching farm equipment types and sizes to job requirements is subject to engineering principles of tooling up for production. These principles are means of interpreting and balancing fixed and variable costs, labor and machine costs, quantity and quality of output, reserve capacity, peak loads and timeliness values, obsolescence and service costs, land and building investment, production plans, capacities of related pieces of equipment, relative capacities of available labor, machines, structures, and land, along with other factors, as indications of the types, sizes, and amounts of equipment which can be expected to give a farmer greatest satisfaction, return, and future purchasing power from his farming operations.

Operating farm equipment efficiently involves application of engineering principles of adjustment, speed, loading, routing, service routine, sequence of operations, combining operations, equipment teams, row length, turning time, idle time, choice of fuel, working when conditions are favor-

able, and a lot of other factors influencing cost and value of the work done. More basic data, reduction to principles, and guides to the application of these principles are needed to help farmers operate their equipment most effectively on any specific job.

Farm practice research, by this or any other name, is a big job and a big opportunity. It is a job which any and every manufacturer of farm equipment might well undertake to do thoroughly and continuously, so far as its line is concerned, in the interest of developing and demonstrating the fullest usefulness and farm value of its products. It is a matter of good agricultural engineering, good economics, good showmanship, good customer relations.

So far as we know, the farm equipment industry has neither sought nor found prosperity in the repair and replacement business created by equipment being worn out or broken prematurely through misuse, nor in the one-time sales of equipment poorly adapted to the farms or jobs on which it is to be used. The industry can increase its opportunity to render genuine economic service, and provide a firmer basis for its future prosperity, by undertaking more farm practice research to help farmers realize the full potential use value built into its products.

Billion-Dollar Cushion

SOME day World War II will have run its course. The external menace to our peace will be temporarily minimized. The bottom will drop out of our war-supply export trade. Other export trade opportunities may be limited. Our own national defense "catch-up" program will get caught up, and if not actually decreased, will level off at some maintenance demand for men and materials which will be less than its present expansion demand. That part of our manpower and production which measures the difference between profit and loss, between prosperity and depression, between labor shortage and unemployment, will need to be redirected into other activities. We will have to return to thinking in terms of peacetime prosperity, a balanced national budget, and reduction of the national debt.

The greatest danger to our prized democracy and its institutions at that time will be our own internal economy. It will be another national emergency! It will be an emergency of providing or creating extensive opportunity for every man to apply his brain and brawn to national resources in a way of his own choice, to produce efficiently, directly or in exchange value, individually or collectively, and to the limit of his effective desire, things that he needs and wants. The only other alternative is a reversion within our country toward the age-old, uncivilized, anarchistic struggle and insecurity of getting and having, not by production and economic service, but by taking from others by trickery, connivance, and brute force.

We can see now that it would have been better to have anticipated and started preparing for our present defense emergency five or ten years ago. Likewise, it should be apparent that now is the best time to start thinking about and preparing for this future crisis. Important as the present emergency may be, budgeting all of our thought to it can only bankrupt us of plans for avoiding or minimizing this future emergency. Backed by our experience during and since World War I, we should be able to anticipate this day of post-war reckoning with greater wisdom than in 1918.

Apparently we still have a surplus of manpower and leadership over what we may need to meet our present problems. Let's use some of (Continued on page 74)

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Water Conservation on the Great Plains

By F. C. Fenton

FELLOW A.S.A.E.

SUBSOILS of the plains regions are dry. Except in the river and creek valleys, there is no reserve moisture in the subsoil which plants may draw on for their supply. Plant growth depends upon the moisture existing in the upper 4 or 5 ft of the top soil. Experience has shown that this soil moisture must be present at the time the winter wheat crop is seeded in the early fall if a profitable crop is to be harvested the next season.

In spite of the low annual rainfall of the region, rains of high intensity are common, and runoff and erosion are severe. There is an interesting difference of opinion with regard to runoff in this region. Those in charge of downstream gaging stations record the fact that the total runoff

is of minor importance. The Kansas river basin upstream from Topeka, with a drainage area of 30,000 sq mi, has an average annual runoff of one inch, or about 4 per cent of the average rainfall of 24 in. Some smaller western Kansas river basins have only 0.5 in of annual runoff as measured by a gaging station. Some contend that runoff is of no importance; that we have in these regions little water to conserve. On the other side, and greatly in the majority, are those who contend that the loss of water from crop land is serious and that soil erosion resulting from this runoff is severe. Evidence of serious runoff from farm land is easy to secure, but concrete quantitative data are still rather limited.

Rainfall and runoff records from the Fort Hays federal soil conservation experiment station plots show that in one year 25 per cent of the rainfall ran off from fallow plots. Sometimes as much as 70 per cent of a certain rain escaped from the fields. Although the total amount of rainfall is small, the high intensity of rains results in large losses by runoff from fallow fields. While the total runoff measured at downstream points is not large, the loss from cultivated fields is serious because of the shortage of water. The entire region is soil moisture conscious because, no matter how well a crop may appear on the surface, the plains farmer knows that if soil moisture is lacking, the crop will probably wither and burn up before maturity. Hence, the great emphasis upon methods of handling the soil and crop so that the precipitation which falls on the land can be stored in the soil and not allowed to run off. Practices which are gaining in favor and in use are (1) summer fallowing with new tillage practices, such as basin listing and contour tillage, (2) terracing, (3) contour farming, (4) strip cropping, (5) pasture furrows, and (6) pond construction.

Summer Fallowing. This is an old and proved practice of water conservation for crop production. New tillage methods which aid in holding the water are making this practice more effective. Effective summer fallowing means keeping the land entirely free from growing vegetation and the surface in condition to absorb water. The dry soils of the plains are capable of absorbing and holding great quantities of water. Of the factors which affect the ability of a soil to absorb water, four which are subject to some modification by human effort, are the porosity of the soil, the organic content, the extent and kind of vegetative cover, and the surface conditions. Soils and crops men have for many years pointed out the value of organic matter in increasing the water-holding capacity of soil. The role of vegetative cover has been reemphasized and clarified by experimental evidence brought out by the U. S. Soil Conservation Service. Grass reduces runoff in a very marked degree and holds more water on the land where it falls, but doesn't store water in the soil permanently in the plains region because transpiration from the grass more than offsets the added water retained. Grass is valuable for soil conservation but not for water conservation on crop land.

In order to reduce runoff from fallow land, emphasis has been placed on tillage methods of holding the water.

Presented before the Soil and Water Conservation Division at the fall meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 5, 1940. (Contribution No. 93 of the agricultural engineering department, Kansas State College.) Author: Professor and head of agricultural engineering department, Kansas State College.



FIG. 1 (Top) Basin listing on the contour holds water where it falls. It is a good method of summer fallowing. FIG. 2 (Bottom) Terracing and contour listing create many small dams which delay runoff and save water.

The lister and duck-foot cultivator are efficient summer fallow tillage machines. Lister furrows running down the slope promote runoff and hasten erosion, so the practice of making dams in the listed furrows has developed rapidly. Many different machines are now on the market for doing this job. All leading manufacturers of tillage machines have a basin lister attachment. In addition to these, many special devices have been constructed, such as offset disk harrows and pock-making machines. The object of all of these tillage operations is to provide surface storage and prevent runoff. The larger basins made by attachments for standard listers seem to be the most effective. When the lister rows are on the contour these dams seem to provide storage for a 2 or 3-in rain of great intensity. These basins also catch winter snows to a certain extent but less effectively than vegetation like sorghum stalks or even Russian thistles.

Basin listing has spread rapidly through the plains region; in some sections it is the established tillage practice. The main objection to basin listing is the added power cost to build these dams. Tests conducted at the Kansas station indicate that the damming attachment to an ordinary lister increases the draft by about 25 per cent. Also a basin listed field is not in good shape for tillage to prevent weed growth. In order to kill all weeds, the dams must be broken out and reformed or the ridges split and new furrows and dams constructed. Many of the different kinds of hole-digging devices now used require less power, but they create much less storage capacity for water. If the basins are not adequate to hold the rainfall, they break over, causing serious erosion. No carefully controlled experiments are available to show just how much soil moisture can be conserved by these methods, but unofficial farmer reports are numerous and optimistic. On the Fort Hays station in the fall of 1935 a basin listed field on a 4 per cent slope held all of a $2\frac{1}{2}$ -in rain which fell in 30 min. On bare, sloping ground and on ordinary listed land, more than half of the water ran off. On the Colby station in northwestern Kansas, soil moisture samples taken after a heavy rain showed moisture penetration 20 in deep on the basin listed field, while on the unlisted field, moisture had penetrated only 10 in.

The period from wheat harvest in early July until seeding time in October offers an ideal opportunity to store some soil moisture for the next crop. This is essentially a three-months' summer fallow period between crops, when the land can be basin listed to catch the summer rains which are usually torrential in nature.

Terracing and Contour Farming. On the large areas of the plains with moderate and rather regular slopes, contour farming has met with much favor. Although thousands of acres are contour farmed without terraces, the terraces are a sound basis for farming on the contour. They serve as a permanent guide for the contours and also serve to prevent overflow and erosion at points where the contours are not entirely accurate. Row crops listed on the contour provide effective water conservation because each furrow and ridge is a dam capable of holding considerable water. Farmers have reported increased yields of wheat and sorghums when farmed on the contour compared to adjoining areas cultivated in straight rows. This is also one of the practices approved by the AAA as a soil conservation measure, and for complying, a farmer is paid at the rate of \$1.50¹ for 6 acres of crop land listed on the contour. In addition to payments for contour listing, a farmer may earn benefit payments for terracing at the rate of \$1.50¹ for 200 lineal feet of terrace construction according to approved standards.

¹1940 A.A.A. payments.

Strip Cropping. The practice of strip cropping is a logical outgrowth of contour farming. Contours are seldom parallel over an entire field and land devoted to row crops must have "point rows". By combining two or more crops, such as wheat and sorghum, the rows can be parallel and the wheat can take up the irregular areas between the rows. This system has operated effectively in the plains region with strips of wheat and grain sorghums 100 to 200 ft wide. The sorghum stubble protects the wheat land from wind erosion and the furrows reduce the runoff. Here again terraces have been found to be valuable where there is a drainage pattern formed by runoff of previous years. Strip cropping alone will reduce runoff but will not entirely prevent erosion and gullying.

Pasture Furrows on Contour. Pasture furrowing on the contour is another new practice widely used to hold some water and increase the moisture available for grass. Following the destructive droughts of 1934 to 1935, a great deal of the buffalo grass on western pastures was dead. These pastures were subject to heavy runoff and severe erosion. These furrows caught the water and held the soil while the grass was reestablishing itself. The heavier growth of grass on these pasture contours shows the value of the water saved.

Pond Construction. The water shortage suffered during the years beginning with 1934 speeded up the movement for farm pond and lake construc- (Continued on page 48)



Fig. 3 (Top) Contour pasture strips increased the growth of grass by retaining water on the land. Fig. 4 (Center) Over 5,000 pasture ponds have been constructed in Kansas. Fig. 5 (Bottom) Level terraces hold water; on porous soil they have proved to be practicable

Effect of Short-Wave Irradiation on Farm Animals

By Truman E. Hienton

FELLOW A.S.A.E.

SHORT-WAVE, or more specifically, ultraviolet irradiation of livestock and poultry is a phase of farm electrification which has challenged the imagination of members of the A.S.A.E. Rural Electric Division for several years past. That challenge still exists despite the studies of research men in vitamin D nutrition and those of illumination engineers in perfecting new lamps which radiate ultraviolet energy.

According to a recent book of that name, vitamin D is shown to be a generic name for a class of substances possessing antirachitic properties*. The most common method for formation of vitamin D is that of exposing certain sterols to ultraviolet light. Sterols are organic compounds that occur in foods as well as in the bodies of humans and animals. Thus, direct exposure to sunlight will form vitamin D in the body of a human being or animal by its action on the sterols in the skin.

Ultraviolet is frequently divided into three sections: near, middle, and far ultraviolet. The middle section, or the band included between 2800 and 3200 Å (Angstrom units) is the band with which we are chiefly concerned in the irradiation of farm animals and poultry. There are three principal wave lengths of mercury radiation in this band: 2967, 3022, and 3129 Å.

A report by Knudson and Benford⁴ contains some valuable information on the rachitic healing effects of spectral energy with rats in these three wave lengths and three shorter ones, namely 2653, 2804, and 2894 Å. The first two are of the shorter wave lengths of ultraviolet radiation that do not appear in sunshine reaching the earth's surface. Of the entire group, line 2804 Å was the most potent and 2967 Å of next greatest potency. Wave lengths as short as 2960 Å may reach the earth's surface⁹ in summer under good conditions in the north temperate zone when the atmosphere is free from fog, dirt, smoke, etc.

TABLE 1. CHARACTERISTIC RACHITIC HEALING EFFECTS OF SPECTRAL ENERGY*

A	Energy necessary to produce 2 + healing microwatt min.	Energy necessary to produce 2 + healing ergs	Comparative efficiency with respect to 2804 Å per cent	Energy for formation of unit of vitamin D ergs
2653	1,581	948,600	79	287,000
2804	1,245	747,000	100	226,000
2894	2,175	1,305,000	57	395,000
2967	1,545	927,000	81	280,000
3024	3,210	1,926,000	39	553,000
3128	135,000	91,000,000	1	27,545,000

*Reproduced from The Journal of Biological Chemistry, Vol. 124, No. 1.

This work⁴ is important to those interested in the possibilities of irradiating animals, since it should aid them in selecting lamps for that purpose, when combined with data on their radiation output. Data for several of the various types of lamps are available from the manufacturers.

Presented before the Rural Electric Division at the annual meeting of the American Society of Agricultural Engineers at State College, Pa., June 17, 1940. Author: Associate in agricultural engineering, Purdue University Agricultural Experiment Station.

*Superscript figures refer to bibliography appended to this paper.

Examination of these values show how weak relatively the 250-watt CX lamp is in comparison with several of the mercury lamps in those wave lengths (2804 and 2967) found most efficient by Knudson and Benford. A comparison of the 250-watt CX and 100-watt S-4 lamps discloses that radiation in those bands from the CX lamp is from 1 to 7 per cent as great as from the S-4 lamp.

The amount of study which has been made in animal and poultry nutrition with vitamin D is so great that a review of the present situation can be made only by referring to similar recent summaries by men in that field. A paper by W. E. Krauss⁵ enumerates requirements of vitamin D for various classes of livestock, from which paper the following material is extracted:

"Horses. Accurate data regarding the vitamin needs of horses are sadly lacking. Unlike the conditions that apply to swine, vitamin D has not been demonstrated to be effective in overcoming unfavorable calcium-phosphorus ratios.

"Swine. Early investigations on the vitamin requirements of swine were confined to the fat-soluble factors A and D, both of which have been shown to be essential to the point that under certain conditions special supplements containing them need to be used.

"Of fundamental significance in this connection is the recent work of Johnson and Palmer³, which demonstrated that not only do pigs require vitamin D, but that there is considerable variation among breeds and even among pigs of the same breed in this requirement. It was also shown that the reduced plasma-calcium values resulting from a lack of this vitamin have a pronounced effect on growth and feed consumption, and that white pigs are less apt to become rachitic than colored pigs under similar conditions in the winter.

"Sheep. As in the case of horses, knowledge regarding the requirements of sheep for the various vitamins is meager. That vitamin D is needed by sheep was established some time ago, but the actual requirement for this factor must be low, since it has been possible to use successfully corn silage as the only roughage in the winter ration of pregnant and nursing ewes.

"Dairy Cattle. Little is known regarding the requirement of vitamin D for production and reproduction. It seems quite certain, however, that when cows are fed sun-cured hay in normal amounts, no additional vitamin D is indicated. Olson⁷ found that dairy cattle can be raised to producing age and will reproduce and produce normally, at least during the first lactation, in the absence of direct sunlight. At the Ohio agricultural station⁶ no greater milk production resulted from treating cows with ultraviolet light during the winter to the extent of the equivalent of 16 hours of midsummer sunshine. When both sunshine and sun-cured hay are withheld from mature cows, however, marked effects are observed, showing definitely that some vitamin D is needed. Under such conditions, Wallis¹⁰ found that the total calcium and phosphorus of the blood were far below normal, that structural malformations developed, and that negative calcium and phosphorus balances prevailed. Milk production was reduced and some irregularities in breeding and calving were observed.

"When animals are pastured in summer and fed sun-cured hay in winter, there would seem to be no cause to worry about vitamin D deficiency. Fall and winter-born dairy calves, however, because of confinement, lack of capacity for roughage, and lowered vitamin A and D content of their dam's or herd milk, pass through their first two months at what might be suboptimum levels of these two vitamins. This constitutes one period when supplemental vitamin A and D feeding might be justified, although Archibald and Parsons¹ obtained some beneficial effects by using a vitamin A supplement in a dairy ration."

The need for vitamin D in chick and laying rations, especially during the winter is well recognized as a result of research work done by many state experiment stations and the U. S. Department of Agriculture. The use of ultraviolet lamps for irradiating chicks and laying birds has probably received more attention than similar irradiation of animals. Recent work with these lamps has been done at Cornell and Purdue Universities.

During the past two winters three pens of laying pullets have been irradiated 8 hours daily with 250-watt CX lamps at a distance of 30 in under the direction of Purdue research men in poultry and agricultural engineering. There has been no increase in egg production or hatchability for the irradiated pens in comparison with check pens, both pens receiving one per cent cod liver oil. A report² of recent work at the University of Wisconsin states that "percentage of hatchability rose and fell directly as the total hours of sunlight during the two-week period before the eggs were laid. Exactly what sunlight contributed to bring about this effect is not known, but it seems certain that vitamin D was not the critical factor."

Two years work have been completed at Purdue University using 250-watt CX and S-4 lamps for irradiating chicks to 14 weeks of age during the winter, in comparison with their receiving one per cent sardinoil in the mash. Nothing was gained as far as weight and liveability are concerned by the use of the lamps in comparison with those receiving one per cent sardinoil. There was a difference between the chicks irradiated 8 hr daily by a 250-watt CX lamp at 30 in and those irradiated 4 hr daily by an S-4 lamp at 48 in. After six weeks of the feeding trial with those irradiated by the CX lamps, sardinoil was added to their ration. Readings taken with an ultraviolet meter indicated a very small amount of energy radiated in the region of 2800-3200 Å by the CX lamp.

The results obtained thus far at Purdue University have not indicated the impossibility of employing lamps in irradiating chicks and laying birds. Rather, the indications are that much is to be learned about the various effects on the birds of irradiation from lamps and the duration, methods, and amounts of irradiation. Similarly, a lack of information seems apparent on the irradiation of farm animals. Agricultural engineers interested in this phase of farm electrification should aid in initiating and enlarging research work in this field. Agricultural engineers in this research field should cooperate wherever possible with fellow workers in allied fields interested in nutrition and irradiation.

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Water Conservation on the Great Plains

(Continued from page 46)

tion. Large numbers of livestock were sold or slaughtered because of water shortage. Nearly all of the farm ponds in existence at that time were dry when the greatest need for water occurred. It was decided that ponds built in the future should be deeper and better and thus be able to withstand longer periods of dry weather. Ten separate agencies supported by federal and state funds have given aid to the farmers in building ponds since 1932.

In 1911 the state of Kansas passed a law which allowed a reduction in the assessed valuation of land on which a water-storage reservoir was constructed. This reduction of assessed valuation has been changed by amendment a number of times and now provides for \$40 reduction per acre-foot of water stored, but is limited to 40 per cent of the assessed value of the land. The law provided that these dams and the details of the plan must be approved by the engineer of the water resources division of the Kansas state board of agriculture. Up until 1934, the first serious drought year, 84 such dams had been built by the farmers' own labor and initiative. In 1934 the Emergency Relief Committee began to build farm ponds, and in a 13-month period constructed 1,895 additional ponds on farms. Most of these were in the various work relief programs. The AAA, under the range program, has made it possible for farmers to receive payment for the construction of water storage facilities at the rate of 15 cents per cubic yard of earth moved up to 5,000 yd, and 10 cents per cubic yard for earth moved in excess of 5,000 cu yd. On many farms the limited amount of money available did not permit a full payment for the earth moved.

The AAA reports that under these provisions 3,882 ponds were approved for payment during the years 1936 to 1939, inclusive. These ponds were, on the average, about one acre in surface area when full of water and were about 7 ft deep at the deepest point. The 1940 program indicates that some 2500 or more additional ponds were constructed during the present year.

The U. S. Soil Conservation Service has constructed a number of ponds in demonstration areas and also through county associations, largely by the use of CCC labor. Pond construction has been one of the most popular activities. A total of 277 such ponds are reported with an average storage capacity of about 5 acre-feet in each pond. These ponds, in general, are more fully completed and probably better designed than those constructed under the provisions of the AAA.

The sum total value of all these ponds is difficult to estimate. Besides the immediate value for stock water supplies, there is some erosion control value in the filling or stopping of gullies. When one realizes that the evaporation from free water surface in 1934 was 70½ in at Garden City and 66 in at Hays, it is easy to see why a deep pond is necessary if water is to be maintained through dry periods. A rule which is being applied is that the depth of a pond should be twice the annual loss by evaporation. In certain cases the seepage from the reservoirs may replenish ground water supplies in the vicinity and help keep local wells from going dry.

Many of these water conservation measures have been developed to meet the needs of a dry-land agriculture. They have been demonstrated by government agencies, but their future success is largely in the hands of the farmers.

The Purchase of Fencing on Specification

By S. A. Braley

ASSOCIATE A.S.A.E.

THE past few years have seen innovations in all lines of endeavor. Laws have been formulated in attempts to aid the unfortunate and oppressed. There have been experiments by government in finance and economics in an effort to improve trade conditions for the farmer so he could realize more on his products.

While these highly publicized procedures have been going on, industrial plants have been quietly at work toward the same end, but in a different manner. They have been experimenting to produce better materials at equal or lower cost so that the consumer, while not getting more dollars, does get more for those he already has.

This condition is probably best illustrated by the automobile. As recently as 1920, the medium-priced car sold for \$1500 to \$2500, and by the time it had run 15,000 to 20,000 miles, it was practically worn out. Today a car costing one-half as much after running twice as far will still be in good condition.

How has this been accomplished? The automobile has been a scientifically developed machine, and the specifications for materials going into it have been experimentally developed by cooperation with the producers of basic materials. Specifications are set and adherence to them is rigid, with the result that your automobile dollar is today approximately four times as efficient as it was twenty years ago.

This same development has been applied to many other commodities, but on many lesser items the value of the development has been reflected to the consumer only in a limited way, because he has not been informed as to how he should specify his materials to get the most for his dollar.

Galvanized products are of extreme importance to the agricultural industry from the standpoint of sheets, wire and fence. Recently a paper was presented by R. W. Sandelein of the Atlantic Steel Company at the annual meeting of the Wire Association in Cleveland, on the effect of steel analysis on quality of a galvanized sheet, with a certain amount of reference to the effect of analysis of the base metal of the wire on galvanizing quality.

A great deal of work has been done on this latter problem, and it has been found that, under the same conditions of galvanizing, the base metal is all important. The base metal should also have in itself a maximum of corrosion resistance. It has been demonstrated that the presence of copper in steel in specified amounts of 0.20 to 0.30, regularly known as "copper-bearing steel", adds materially to the corrosion resistance of steel.

The quality of galvanizing is determined by three main factors, namely, *adherence*, *uniformity*, and *thickness* or *quantity*; and a fourth may be added, which is *appearance*. Let us now consider the basis of these factors. Adherence is important, because if the adherence is not good any deformation of the material causes a cracking or peeling of the zinc, exposure of the base metal,

and complete loss of the value of the zinc. This, you can readily realize, is particularly important in a wrapped or twisted wire fence and, since no chain is stronger than its weakest link, the protection of the zinc is no better than the protection at the point of twist or warp. Fig. 1 shows two wrapped pieces of galvanized wire. One of these pieces, it will be noted, is badly peeled, whereas the second does not show a crack. These two pieces are taken from material galvanized at one and the same time and illustrate the differential adherence dependent upon analysis of the base wire metal. Other factors contributory to this condition may be quality of the zinc used and the amount applied. The purer the zinc, the greater its ductility, and hence the less probability of its cracking. However, the greater the thickness, the greater the possibility of cracking regardless of zinc quality.

This, then, is a factor to be noted in the purchase of fence, especially hinge joint or wrapped fence. Does the zinc peel at the wraps?

The other important property of a fence is the amount of zinc uniformly distributed on the wire. During the past several years some extensive tests have been conducted by the American Society of Testing Materials, and in a report of Committee A-5 on Corrosion of Iron and Steel, June 1939, certain interesting facts have been recorded. A table in the A.S.T.M. report lists three separate groups of galvanized wires and the results of atmospheric corrosion on them as taken at three different locations, namely, Pittsburgh, Sandy Hook, and State College, Pa. A check of inspection tests on these samples shows the following average values:

Group I		Group II		Group III	
Oz Zn/sq ft	Preece test	Oz Zn/sq ft	Preece test	Oz Zn/sq ft	Preece test
0.813	5 min	0.85	7 min	0.81	4-2/3 min

Note is made that samples in each group have the same base metal composition and coating characteristics. Perusal of the illustrations in the report definitely shows the three groups as three different methods of galvanizing.

However, the three groups show loss of zinc by atmospheric corrosion as follows:

Group I	Group II	Group III
0.399 oz/sq ft/yr	Pittsburgh, Pa. 1.48 yr 0.372 oz/sq ft/yr	0.380 oz/sq ft/yr
0.372 oz/sq ft/yr	Pittsburgh, Pa. 1.94 yr 0.362 oz/sq ft/yr	0.344 oz/sq ft/yr
0.122 oz/sq ft/yr	Sandy Hook 1.44 yr 0.139 oz/sq ft/yr	0.118 oz/sq ft/yr
0.071 oz/sq ft/yr	State College, Pa. 1.3 yr 0.080 oz/sq ft/yr	0.067 oz/sq ft/yr

The first noticeable characteristic of these data is the difference in loss at the various locations. The first, Pittsburgh, Pa., is an industrial area, and these samples are exposed at one of the worst points in the area; the second is at Sandy Hook, where the samples are exposed to coastal or salt water atmospheres, whereas the third is at State College, Pa., a farming area.

A second noticeable feature is that the rate of loss of zinc at the various localities is similar for each group, and hence is not dependent upon method of galvanizing.

The third is that the atmospheric corrosion loss (Continued on page 50)

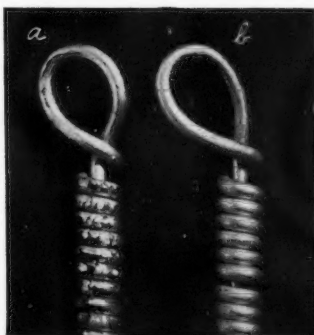


Fig. 1 Two wrapped pieces of galvanized wire, one of which is badly peeled, while the other shows no cracks

Presented before the Farm Structures Division at the fall meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 3, 1940. Author: Chief metallurgical field engineer, rod and wire division, Pittsburgh Steel Co.

National Defense: An Ag Engineering Phase

To A.S.A.E. Members:

WE HAVE heard a great deal about national defense, but probably few of us are familiar with that part of the program which deals directly with agricultural engineering. The U. S. Office of Education has been assigned the duty of administering a program of training for national defense industries. One phase of this program is training for out-of-school young men between the ages of 17 and 25. Designated as the 4A program, it includes training in the following:

- 1 Operation, care, and repair of tractors, trucks, and automobiles, including diesel and gasoline motors
- 2 Metal work, including simple welds, tempering, drilling, shaping, and machinery repair
- 3 Woodworking
- 4 Elementary electricity, including operation, care, and repair of electrical equipment.

The courses arranged for such training are outlined in detail in the U. S. Office of Education Misc. 2603, which is available on request.

This is a general pre-employment type of training designed to give the out-of-school farm youth a basic training in mechanics. All of it involves some phase of agricultural engineering, and most classes are held in high school farm mechanics shops, usually at night. The minimum requirements are ten men meeting 15 hours a week for 8 weeks on each type of work offered. Federal funds are available to pay the cost of instruction, including a limited amount for equipment and supplies. Any one or all four types of work may be given.

It is necessary to employ local mechanics to do the teaching, because there is no other source of trained men. There has never been a time when we needed so many well-trained agricultural engineers as now, and none are available. Local vocational agricultural teachers are not permitted to

teach these courses if employed full time otherwise. Very few of them have been well trained for this type of work and most of them could not teach it if they had time, which is something for us to think about.

What can agricultural engineers do to help? Let us consider first the immediate needs in the field. Students must have equipment with which to work, if they are to get valuable training. Trucks, tractors of all types, graders, terracers, gasoline engines of all types, electrical equipment, machine shop and wood working equipment, and tools for hot and cold metal work are necessary in volume. There is not enough money available to purchase all that is needed, and purchase could not be justified in most cases. Funds are available for renting equipment.

Excellent cooperation is being given by farm machinery manufacturers, county highway officials, terracing cooperatives, CCC and NYA, and many commercial firms.

The agricultural engineering departments in all state colleges and universities can render valuable service in the way of information about materials, procedures, course outlines, teachers, and commercial or other organizations that may wish to cooperate. Perhaps we can help with teacher training or with equipment.

The defense training program is administered in the states by the state board for vocational education, usually through the state director of vocational education. Get in touch with the proper officials in your state at once and offer what assistance you can. This is a national emergency, much more serious than most people realize. May our children depend on us to do our share now to insure their freedom in the future.

M. A. SHARP

Head, department of agricultural engineering, University of Tennessee

EDITOR'S NOTE: Prof. Sharp has been granted a six months' leave of absence from the University of Tennessee to work with the U. S. Office of Education as special representative to direct the program described in his letter, and his territory is Virginia, North Carolina, and Tennessee.

The Purchase of Fencing on Specification

(Continued from page 49)

does not follow the Preece test immersion, and hence this test is not a test for life of a galvanized article.

Since these facts are self-evident, only one conclusion can be drawn. That is that life of the protective coat of zinc is proportional to the actual weight of equally distributed zinc.

This, then, affects the life as follows: The A.S.T.M. specifications list three classes of galvanized wire. The first has a minimum of 0.30 oz of zinc per square foot, the second, 0.50; and the third, 0.80.

These classes then would furnish zinc protection for the base metal wire in a farming area, such as State College, of approximately four years, seven years, and eleven years, respectively, if the corrosion data given above is used as a basis of estimate.

True, there is a difference in the cost of wire purchased on the various A.S.T.M. class specifications, but it is by no means commensurate with the life differential. However, the consumer of fence seldom, if ever, inquires about the quality of fence he is obtaining, but he does inquire about a differential of five or ten cents a rod, which difference becomes infinitesimal when applied to the life differential.

Farm fence is not usually manufactured on A.S.T.M. specifications, but the farm fence consumer can always attempt to purchase the heaviest coated wire he can obtain for an equal or slightly greater cost, and thus know he is

obtaining the most for his dollar of investment in fence.

The fourth factor mentioned above is appearance, and this can also be requested. Like a new toy or automobile, brightness of the article is desired. Some fences appear bright when purchased, but the method of application of the zinc, with its resultant small amount, causes the fence to lose its brightness quickly. Others, using methods of application which give somewhat greater amounts of zinc, appear dull and gray even when new, and they also soon become unattractive, while a third or fourth method produces even heavier coatings which will have an attractive metallic lustre which will eventually lose its sheen, but remain metallic and white and have an attractive appearance throughout its life.

To sum up the qualities to be considered, we have the following:

1 Does the base metal of the fence have the greatest corrosion resistance, once the protective zinc coat has corroded away?

2 Is the base metal of such composition that the zinc adheres sufficiently so that normal distortion of the wire during fabrication does not cause it to crack and peel?

3 Is the amount of zinc on the wire the most that can be obtained without excessive extra cost?

4 Will the fence maintain approximately the same lustrous finish that it has when purchased?

Observations on the Storage of Grass Silage

By H. E. Besley and J. R. McCalmont

MEMBER A.S.A.E.

MEMBER A.S.A.E.

GRASS silage has been defined as silage made from any uncured hay or forage crop. Its use has become widespread during the past few years, and, as a result, some problems have arisen that require engineering research for solution.

Silo deterioration and failures brought demands from farmers for assistance, and to meet this demand an investigation was instigated at the New Jersey Agricultural Experiment Station in 1937, with the cooperation of the Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, to measure the pressures exerted on silo walls by grass silage. The project has now been expanded to include investigations on juice control, protection of silos from the action of silage acids, and harvesting methods and machinery. This expansion has been materially assisted by a research grant made jointly by the American Steel and Wire Company, the Carnegie-Illinois Steel Company, the National Association of Silo Manufacturers, and the Portland Cement Association.

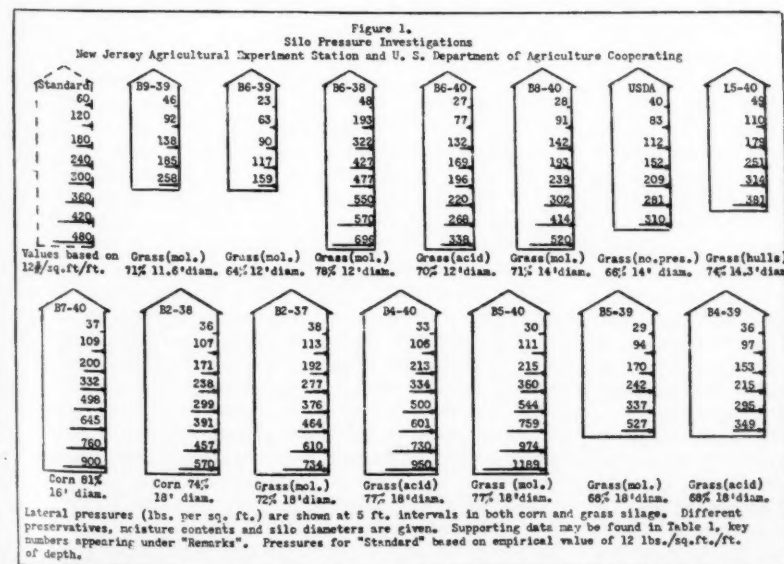
In the past when a silo failed, it burst. Now that leakage is more prevalent, farmers have become juice conscious and are demanding silos that will not leak. The term "failure" has gained broader meaning, and a silo may be said to fail not only if it bursts, but also if it leaks, deteriorates, or disintegrates. While this definition may not be universally accepted, it does indicate a condition that must be met in silo design.

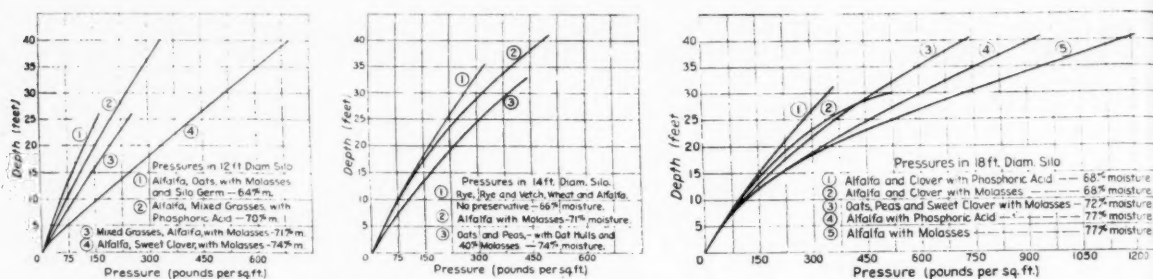
Juice in grass silage presents a sort of "polyphase" problem. In high-moisture silage it may, and frequently does, leak or drain from the silo, causing offensive odors, damage to any concrete or metal reinforcing over which it flows,

and some loss of nutrients. Its control may be approached in several ways. One is to wilt the green crop in the field until its moisture content is lowered to between 65 and 70 per cent. Reports from farmers indicate some success with this method, but considerable experience is required to determine when wilting has progressed to the proper stage. Wilting is also dependent on favorable weather, and the introduction of a fair weather factor in the production of grass silage is not desirable. A second method is to add to the chopped material some dehydrated preservative such as oat hulls or citrus pulp, fortified with molasses, to absorb the free moisture. It will be noted in Table 1 that two silos, L5, 1940 and B1, 1938, were filled using this type of preservative and that there was no leakage, even with the high-moisture green material. Corn meal and ground ear corn are now being tried as moisture-absorbing preservatives. A third method reported as practiced by middle western farmers is to use a longer cut on the chopper when ensiling material of high moisture content. Along this same line, one ensilage cutter manufacturer is advising farmers to vary the length of cut with the condition of the green material, suggesting $\frac{1}{4}$ in for low moisture, $\frac{1}{2}$ in for average, and 1 in for high moisture. This sounds promising and should be investigated under controlled conditions.

In some instances it may be desirable to rid a silo of free juice. Therefore, considerable thought is being given to drainage systems for silos and to preventing seepage at points other than drains. In 1939 three drains were placed in the walls of two 18-ft silos (B4 and B5, Table 1). One of the three drains was a 1.5-in pipe placed opposite the doorway and flush with the inside wall and foundation. The other two were 2.5-in pipes placed about 6 in above the foundation and opposite each other in the wall midway between the first drain and the doorway. One silo was filled with 188 tons of phosphoric acid grass silage, and the other

was filled with 198 tons of molasses grass silage. The average moisture content of the ensiled material in each case was 68 per cent. The drainage loss from the acid silage was 975 gal of juice, representing 2.24 per cent by weight of the ensiled material. Drainage from the molasses silage was 3,990 gal, representing a loss of 9 per cent. A point of particular interest is that all of the juice lost from the silos came through the drains. For 1940, using the same two silos, one was filled with 333 tons of phosphoric acid grass silage and the other with 318 tons of molasses grass silage, moisture content in each case being approximately 77 per cent. The leakage loss from the acid silage amounted to almost 16 per cent, while the loss from the molasses silage was about 18 per cent of the total ensiled weight. The drains functioned, but carried only part





Figs. 2 (Left), 3 (Center), and 4 (Right) Pressures in silage of various materials, at different depths, in silos of different diameters

of the leakage. Most of the additional loss occurred around the doorway, as expected, because of the pressure panel construction. Some leakage through the stave joints occurred up to a height of 18 ft in each silo. The joint leakage in 1940 was associated with the higher pressures, which amounted to almost twice the values measured in 1939. A rock fill about 3 ft in diameter with drain in the bottom was used in silo B6 in 1940. Filled with 97 tons of phosphoric acid grass silage at 70 per cent moisture, the seepage amounted to approximately one per cent, all coming through the drain. Other types of floor drains and vertical wall drains are to be tried.

The hoops on silos B5 and B8 were tightened to produce a stress in the steel of approximately 18,000 psi so that the staves might be held together with some force even after the silos were filled. Preliminary observations indicate that prestressed hoops will limit the leakage through the vertical joints of concrete stave silos but cannot be expected to control entirely the leakage problem because of the irregular joint surface found on concrete staves. Horizontal joint leakage was more noticeable when the vertical joint leakage was reduced. In prestressing hoops, considerable difficulty was encountered in holding the stress on intermediate hoops that do not cross the door opening but are held by spreaders. Faulty design, particularly on spreaders carrying more than one hoop, has been evident. One common fault has been the reduction of effective area of the spreader strap by rivet holes. Improvements that have been noted include the use of continuous heavy angles along the door opening, instead of spreaders, to which the hoops are attached. The angles are held by heavy rods across the door opening at sufficiently wide intervals so as not to interfere with the removal of silage. Welding to strengthen riveted members is also in evidence.

Plastic calking was placed in most of the horizontal joints of three courses of staves in silo B8 to observe its effectiveness as a joint seal. From this one test the value of the calking may be questioned, as there was a small amount of joint leakage in the bottom two stave courses with little to choose between calked and uncalked joints.

To effectively seal the interior and protect the concrete stave silos, some 24 different coatings have been applied. The materials include asphalts, coal tars, oils, paraffin wax, rubber paints, synthetic resins, special plasters, varnish, and waterproofing. Results to date have not been promising. It has been difficult to get a lasting bond between the coating and the concrete. Tests of coatings are also underway in tile block silos, where difficulty has been experienced in maintaining the mortar joint, and in steel silos. More durable mortar must be found for block silos as the types now used disintegrate rapidly and leave the reinforcing exposed to the action of silage acids. This will reduce the area of steel and weaken the silo if allowed to continue.

Considerable work has been done in the past on the

strength and durability of concrete and concrete staves and protective coatings for concrete. Probably the most extensive work along this line has been a cooperative project between the U. S. Department of Agriculture and the agricultural experiment station of the University of Minnesota, under the direction of D. G. Miller. The results of some of these tests pertaining in particular to concrete stave silos were published as Paper No. 1713, scientific journal series of the University of Minnesota¹. While many means of protecting concrete and mortar from acids have been studied, as yet no substitute for a rich, well-proportioned mix has been found.

The Portland Cement Association has cooperated with several state agricultural experiment stations in making studies of various protective coatings for masonry silos. As a result of their work, they recommend several coatings that may be effective for from 1 to 5 yr. The American Concrete Institute, through its committees, is also investigating means of prolonging the useful life of silos.

Equipment being used to measure pressures in silage was developed by the Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, and information on it has been published². Silage pressures have been measured in seven silos at the New Jersey station and one at the Beltsville research center of the Department of Agriculture, aggregating twelve tests on grass silage and seven on corn silage. Readings were taken as each 2 or 2½-ft layer of silage was placed in the silos, so that the number of individual panel readings taken during the filling of the various silos ranged from 75 to 150, with additional readings being taken each morning and evening during filling and each day during the settling period. The panels averaged about 4 sq ft in area. Results are quite variable as may be seen from Fig. 1, which summarizes the lateral pressures. Maximum values for grass silage vary from 159 lb per sq ft in a 12-ft diameter silo with 64 per cent moisture silage at a 25-ft head, to 1189 lb per sq ft in an 18-ft silo, with 77 per cent moisture silage at a 40-ft head. This is a range of from approximately one-half to two and one-half times the pressures commonly considered in silo design, which is 12 lb per sq ft per ft of depth.

Factors that affect the amount of lateral pressure on silo walls, in addition to depth, are the moisture content of the silage and its distribution, the preservative used, the diameter of the silo, the fineness of cut, speed of filling, and type of material ensiled. The twelve tests on silo pressures with grass silage that have been run to date show the effect of moisture content and the type of preservative. Figs. 2 and 3 show how the pressures in 12 and 14-ft diameter silos increase as the moisture content increases. There are some

¹Miller, Dalton G., Manson, Philip W., and Rogers, Charles F. Laboratory tests of concretes and mortars exposed to weak acids. *Ag. Engr.* Vol. 20, No. 11 (November 1939).

²McCalmont, J. R. and Besley, H. E. Silo pressure and temperatures with corn and grass silage. *Ag. Engr.* Vol. 20, No. 6 (June 1939).

TABLE 1. SILO INVESTIGATIONS — GRASS SILAGE DATA^a

Silo size, ft ^b	Material ensiled	Preservative added Kind	lb/ton	Total tonnage	Moisture content in silo, per cent ^c	Settled depth, ft ^d	Max lateral pressure, lb/sq ft	Remarks ^e
11.6x28.5	Mixed grasses and alfalfa	Molasses	77	80	71	24	258 (25-ft head)	NJ, B9, 1939. Good silage, some moldy spots near top. No leakage.
12x28	3rd alfalfa and oats	Molasses and silo germ	43	49	64	22.5	159 (25-ft head)	NJ, B6, 1939. Top spoilage. No leakage. 24 tons high-moisture oats on top of 24 tons low-moisture alfalfa.
12x41	2nd alfalfa and clover	Molasses	125	159	78	33	696 (40-ft head)	NJ, B6, 1938. Excellent silage. Severe leakage.
12x41	2nd alfalfa	Phos. acid	24 and 24 water	97	70	34	338 (40-ft head)	NJ, B6, 1940. No leakage, approximately 1 per cent seepage from floor drain.
14x43.5 (incl. 6-ft pit)	Cereals and alfalfa	None		106	66	38.5	310 (35-ft head)	U.S.D.A.
14x42	2nd alfalfa	Molasses	87	141	71	36	520 (40-ft head)	NJ, B8, 1940. Some leakage, approximately 2 per cent loss, cutter set at 1/4-in cut.
14.3x35	Oats and peas	Oat hulls with 40% molasses	100	115	74	28	581 (30-ft head)	NJ, L5, 1940. No leakage.
18x31.5	Alfalfa and clover	Molasses	106	198	68	27.5	527 (30-ft head)	NJ, B5, 1939. Good silage, 9 per cent seepage loss through drains.
18x32.5	Alfalfa and clover	Phos. acid	20	188	68	27.5	431 (32.5-ft head)	NJ, B4, 1939. Good silage, 2.24 per cent seepage loss through drains.
18x35	Oats and peas	Citrus pulp and molasses (dry)	100	189	75 (green material)			NJ, B1, 1938. Top 6 ft spoiled, rest very good. No leakage.
18x40	Alfalfa, clover, and timothy	Molasses	27	265	Ave			NJ, B5, 1937. Poor silage, offensive odor, moldy spots. Leakage at doors.
18x40	Mixed grasses	Molasses	100	210	Low			NJ, B5, 1938. Top spoiled, also along sides down 10 ft. No leakage.
18x40	Alfalfa	Phos. acid	20	333	77	35	950 (40-ft head)	NJ, B4, 1940. Severe leakage, approximately 16 per cent loss.
18x41	Alfalfa	Molasses	66	318	77	35	1189 (40-ft head)	NJ, B5, 1940. Severe leakage, approximately 18 per cent loss.
18x42.5	Oats and peas	Molasses	40	268	72	37	801 (42.5-ft head)	NJ, B2, 1937. Good silage. Leakage from lower 5 ft about 3 weeks after fill.

^aMessrs. Claude Eby and W. H. Tamm. N. J. Agr. Exp. Sta., assisted in preparing data for table.

^bRefers to silo diameter and depth of silage immediately after filling.

^cLow moisture content assumed to be below 65 per cent, average 65-72 per cent, high over 72 per cent.

^d30 days after filling.

^eN. J. cutters set for 1/2-in cut except as noted.

All N. J. silos sealed with mulch paper covered with at least a ton of chopped grass.

Spoilage refers to silage unsuitable for feed below seal. Silo types: N J B1 to B8 incl. — concrete stave; NJ B9, L5 — steel.

differences in the type of preservative used in these silos, but since the moisture content varies in each case and there are some differences in the materials ensiled with different preservatives, no direct comparisons on the effect of preservatives can be made for these silos. Fig. 4 demonstrates the effect of both moisture content and preservative in 18-ft diameter silos. Curves 2 and 5 show the increase in pressures with molasses silage over the pressures with acid silage given in curves 1 and 4. Since the silos represented by curves 1 and 2, also those represented by curves 4 and 5, were filled simultaneously, the effects of diameter, material, and moisture content were eliminated, and all the differences can be attributed to the preservative. Similarly, the increase in pressure found when comparing curve 1 with 4 and curve 2 with 3 and 5 can be attributed to moisture content. The fact that curve 2 crosses curve 3 between the 25 and 30-ft levels can be ascribed to the difference in the material ensiled in the two silos, and the fact that the silo represented by curve 2 had the bulk of the low-moisture material in the bottom part and comparatively high-moisture silage on top, while the silo represented by curve 3 was filled with silage of a uniform moisture content throughout.

Silo capacity, as well as pressure, is influenced by moisture, silo size, and fineness of cut. It has been observed that with grass of average moisture, taken as 65 to 72 per cent, the smaller or average sizes of silos will hold about the same tonnage of grass as corn. Those holding a greater total tonnage of grass are about balanced by those holding less. As the moisture content is increased, the total tonnage is increased, and vice versa. Silos filled with high-moisture grass have held up to 50 per cent greater tonnage than would be expected with normal corn silage. In each case,

however, the variation of the dry matter capacity of the silo is slight.

SUMMARY

Foundation drains show promise of satisfactory operation, particularly when pressures are not excessive.

Vertical joint leakage from concrete stave silos may be controlled to some extent by prestressing the hoops. Joints must be redesigned or provided with seals before general satisfaction can be expected.

Results of the New Jersey tests on coatings for concrete are not at all promising. However, other observations seem to indicate that varnishes and synthetic resin with wood oil vehicles, asphalts, coal tars, and Portland cement washes show promise of giving some satisfaction. In choosing an asphalt or coal tar preparation, care should be taken to select one that has a high melting point in order to minimize sticking of the silage³.

Silos should be adequately reinforced⁴. Silos with exposed reinforcing are likely to be more satisfactory for storing high-moisture silage than those with reinforcing concealed in the mortar joint because of the likelihood of the mortar failing and leaving the steel exposed to the action of the silage acids. Exposed reinforcing can also be prestressed, thereby lessening the tendency for cracks to open in the walls. It can also be inspected at will and repairs or replacements easily made when necessary.

Under usual farm conditions the average size silos will hold about the same tonnage of grass as of corn.

³Some suggestions regarding silo coating are given in Bulletin CP 14 of the Portland Cement Association.

⁴Adequate reinforcing schedules are given in Tables 8 and 9, U.S.D.A. Farmers' Bulletin 1820.

Relation of Agronomic and Nutritional Factors to Engineering Problems and Farm Practices in Making Grass Silage

By T. E. Woodward

THE practice of siloing hay crops has increased rapidly during the last few years, but so far perhaps less than 5 per cent of all silage is made from these crops. Crops are converted into silage primarily to save what would otherwise be wasted or lost, rather than to make a better feed. For example, one-third to one-half of dry corn stover fed unchopped or unshredded is refused by cattle, but if it is made into silage there is no waste at all. Not only do cattle refuse the coarse parts of hay, but unless the weather permits rapid curing, the hay would lose more nutrients in the field than in the silo. Converting a crop into silage, therefore, may lessen the losses of food nutrients and also the waste in feeding.

SILAGE OFFERS WEATHER ADVANTAGE

Silage is superior to good hay in feeding value in only one respect. It contains more carotene and this gives the milk a higher color and a higher vitamin A content. Some few dairymen with a special market are able to realize some monetary return on the production of high-color milk, but by far the larger number receive no premium for such milk. Until the dealer or consumer is willing to pay more for high vitamin A milk, there is no immediate financial advantage in a farmer's feeding any more carotene than is required to maintain the health of his herd, and the amount necessary for this purpose would be contained in good hay.

Cattle do not need the succulence of silage. So long as they have plenty of water to drink they will thrive as well on dry feed as on wet feed, maybe better. They will eat as much dry matter in the form of good hay as in the form of silage. Making a crop into silage is an ineffective means of increasing the consumption of roughage, if the crop can be made into good hay with certainty. Furthermore, more hours of labor are required to make silage than to make hay, but because of less interference from the weather, a crop can often be put in the silo in fewer days than it can be made into hay. Silage making increases the labor but may save time. There is practically no advantage in making silage in regions where good haying weather is certain to prevail, or at those times of the year in other regions when the weather permits the making of good hay with certainty.

But weather conditions often prevent the making of good hay, in which case converting the crop into silage is an excellent alternative. Not only will a greater proportion of the nutrients be saved by making silage, but those saved will have a higher feeding value than an equal weight in poor hay. It appears that grass and legume silage will come into use in those regions where considerable poor hay is produced, but not in those regions where the hay is uniformly good.

All forage crops, regardless of species, variety, or stage of growth, can be and are being preserved in the silo suc-

cessfully. This statement is not intended to cover root crops. We have been led to believe that there is a certain amount of magic in the making of silage. We have been told to do this or that or the silage will spoil. As a matter of fact, all that is necessary to keep silage from molding or decaying is to force out the air promptly from the ensiled mass and then keep it out.

How will we force out the air? In two ways. First, chop the material fine. The finer the chopped material, the less space a given weight will occupy, consequently the smaller the amount of air that will be trapped within the mass. Secondly, apply pressure. By this I do not mean that some sort of artificial weighting must be employed. If the silo is of the usual depth, if the material is reasonably moist and heavy, and if the silage is topped off with 2 or 3 feet of heavy green material, the natural pressure will be sufficient to force out the air. This is one reason for always putting a thick layer of dirt on trench silage. The lower the moisture content of a crop, the less a given volume will weigh; the lower the weight, the less will be the pressure exerted, and the greater will be the amount of air retained within the mass of silage. For these reasons, it is doubly important that low-moisture crops should be chopped fine. Low-moisture crops chopped into $\frac{3}{4}$ -inch lengths or longer and then put in a shallow silo without weighting the top will surely mold and spoil. Our own practice is always to chop the hay crops, and usually the corn into $\frac{1}{4}$ -inch lengths.

IMPORTANCE OF KEEPING OUT AIR

How will we keep out the air? Simply by having silos with airtight walls and doors and by properly protecting the top of the silage. Grass silage shrinks away from the silo wall at the top more than corn silage does. Our explanation for this is that grass or legume silage mats together in a way that would permit one to build it into a stack or pile with vertical sides, whereas, with corn silage, the base would have to be wider than the top. The corn silage tends to slide horizontally and thereby to close any spaces that may open up between the silage and the wall. Grass silage that is not kept leveled and uniformly packed as the silo filling nears completion is likely to settle to one side or the other as a hay stack settles toward the side packed the least. This will open a space at the top which may lead to spoilage for a considerable distance down the side of the silo. We believe it is a good practice, after the silo is full, to fill in any space that may have opened up around the wall and to tramp the top thoroughly about every two days the first week and about once a week thereafter until the silage is fully settled. The heavy green material with which filling should be completed serves to force out the air from the silage underneath, and tends to prevent the entrance of air from the outside. If these precautions are taken, there will not be an undue amount of spoilage at the top.

The nutritive value of a crop made into silage is similar to what it would be in the green state or when made into

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hay. One can expect little change for either better or worse in making silage. If the crop would make a good feed when made into hay, it would make a good feed if made into silage; and generally if it would make a poor hay, it would make a poor silage, although a weedy or stemmy crop may be put in such condition by siloing that it will be completely consumed whereas a large part of it would be refused as hay. The stage of maturity that makes the best hay also makes the best silage. Incidentally, investigations have shown that seeds from most weeds are entirely destroyed in the silo, and even the seeds from the most resistant species are nearly all destroyed.

The losses of food nutrients can be measured approximately by the losses of dry matter. In properly made silage that is fed out a few months after it is made, the loss of dry matter should not ordinarily run over 15 per cent. It appears that chemical changes continue as long as the silage remains in the silo, and if the storage period extends for a year or longer, one must expect a loss of dry matter in excess of 15 per cent. The losses by siloing can be considered comparable to those that take place in curing good hay and less than those that take place in the curing of poor hay. The principal chemical change is the conversion of some of the starches and sugars to lactic and other acids. The ether extract is increased, but this probably does not mean an actual increase in true fat. Some of the protein is broken down into simpler and more volatile compounds, but these are not necessarily less valuable from the standpoint of nutrition.

In hays, the color is an indication of the carotene content. Brown hays are devoid, or nearly so, of carotene, but brown silages may have a high content of carotene. It appears that carotene disappears through oxidation, also that the brown color of silage can develop without the silage becoming hot. The way to preserve the carotene is to keep out air. Grass silages as a rule have a high content of carotene, provided the crops from which they are made are green and have not become discolored through maturity, frost, or through bleaching by the weather after they are cut.

The moisture content is of paramount importance. During the last few years we have made about 125 lots of experimental silage at Beltsville (Maryland). The results show unmistakably the superiority of low-moisture silage over high-moisture silage, with respect to loss of dry matter during fermentation, and palatability as judged by the quantities of dry matter cows will consume. By low-moisture silage I mean silage with 32 per cent or more of dry matter; by high-moisture I mean less than 32 per cent of dry matter. It is doubtful if there is any preservative that will improve the quality of high-moisture silage, any more than the practice of reducing the moisture by wilting the crop before it is put in the silo. What is the sense in putting a lot of excess moisture in the silo just to allow it to leak out and waste nutrients, to carry much of the preservative with it, to create a bad smell and make an excellent place for flies to breed, to increase the lateral pressure on the silo walls, thus making extra reinforcement necessary, and to damage any concrete or metal work with which the effluent comes in contact? And what is gained in making high-



moisture silage? A little more carotene that is not needed for the well-being of the herd, and a little more color in the milk for which the producer receives no extra compensation. Anyone who has studied the subject must admit that silage wilted enough so there will be no leakage from the silo is better than high-moisture silage.

But let us go back for a moment to the matter of leakage. Our experience is that silage with more than 68 per cent of moisture or less than 32 per cent of dry matter is likely to leak. Judged by the

chemical analyses of the juice, it appears that the waste of nutrients is not the major objection to high-moisture silage, unless the leakage is extensive. We have collected juice from three 10x25-foot silos, two of which were filled with soybeans and one with alfalfa. The soybeans had about 71 per cent of moisture and the alfalfa about 68 per cent. Three per cent of the total weight of the soybeans passed out as juice, and only 0.5 per cent of the alfalfa. The solids in the juice ranged from 6 to 11 per cent, one-third of which was protein, and nearly one-fifth mineral matter. Whether much of the mineral content that is important in animal nutrition was lost was not determined.

There is some evidence that the addition of molasses increases the leakage, but so far as our own work is concerned this evidence is inconclusive. The theory is advanced that molasses, being denser than the plant juice, extracts the juice by osmosis, just as the addition of salt extracts moisture from meat. Our experience is that water-logged silage is likely to be of inferior quality as regards odor and feeding value. We believe it is better to stand the waste in the leakage than to impair the quality of the silage by retaining the excess moisture in the silo.

Our knowledge regarding the feeding of silage is still somewhat fragmentary. We know more about making silage than we do about feeding it. What we need is some carefully conducted feeding trials conducted over the whole barn feeding season in which a ration containing grass silage is compared with a standard ration. Our own experiments indicate that a ration in which medium to high-moisture legume silage is the sole roughage, does not maintain production as well as when either dry hay or corn silage is substituted for part of the legume silage. Other experiments show that good legume silage is approximately equal to good hay on a dry-matter basis, when fed along with corn silage. That is to say, silage with 30 per cent of dry matter is worth one-third as much as good hay with 90 per cent of dry matter. It seems entirely safe to say that, if grass silage does not contain too much moisture, it can be substituted for the hay in a roughage ration of hay and corn silage, also that it can be substituted for a portion of the hay in a ration containing hay as the sole roughage. Whether we can profitably make a more extensive use of grass silage remains to be determined. There seems to be a general opinion that high-moisture silage is not satisfactory as the sole roughage. Whether this would be the case with low-moisture silage is something we do not yet know.

For a number of years our division has been "flirting" with the idea that farmers can store all of their roughage in silos and so do away with hay mows and the consequent

hazard of fire. Last year (1939) we filled two concrete stave silos (10x25 feet) with alfalfa dried in the field as much as it would stand and still retain the leaves. The moisture was a little under 35 per cent. When the moisture gets down to 30 per cent or lower, many of the leaves will shatter off when the hay is handled. This was run through a cutter set for 1/4-inch lengths and the silo topped off with 2 or 3 feet of heavy green alfalfa. The silage (or hay) was of excellent quality and kept well except for some mold next to the wall. The molding was not extensive enough to justify discarding any of the silage. In fact, it was all fed and it proved to be as valuable as good field-cured alfalfa hay. This year we filled an identical silo with the same sort of material containing 31 per cent of moisture. With the thought that the molding was due to air coming through the walls of the silo, we coated a portion of the inside of the silo with asphalt dissolved in gasoline in order to render the wall impervious to air. There was a little mold where we failed to paint, but none at all next to the wall that was treated. This silage is more like tobacco-brown hay than like silage, but unlike brown hay it has as much moisture as it had at the time it was put in the silo, and it has a much higher content of carotene than does hay.

What are the advantages of this kind of silage or hay over field-cured hay? All the leaves are saved, the fire hazard is eliminated, it is consumed without waste, and there is no objectionable dust in feeding, as is the case with chopped hay. What are the disadvantages? The knives and pipe of the cutter gum up the same as they do when field-cured hay is chopped for the mow, only more so; there is so much dust in the silo that men cannot work in the silo when the cutter is running; and special precautions must be taken to avoid spoilage. We are not yet ready to advocate silage with such a low content of moisture, because we are not certain that we can always prevent the growth of mold.

SOME ENGINEERING PROBLEMS

So far I have said nothing in regard to the engineering problems, and since I am not an engineer, perhaps what I do say should not be given too much weight. A serious matter on many farms is the trouble from stones. It would be a big help if engineers could devise some way to avoid picking up stones with the crop, or some way to prevent their going through the cutter when they are picked up.

Field choppers should be so designed that they will either mow and chop or take up from the windrow and chop. This would enable the farmer to silo his crops with the desired content of moisture. If harvesting took place during a dry spell of weather, and especially if the crops were rather mature, he could mow and chop at one operation; but if the crops for any reason were high in moisture he could wilt them in the swath or windrow, and then chop. If a combination implement of this sort is impracticable, it would be better, in my opinion, to dispense with the mowing mechanism instead of the pickup mechanism.

Clogging of the blower pipe is common, especially with finely chopped crops and with crops wet with external moisture. We have often wished for a practicable bucket-type elevator. Such an elevator would materially lessen the requirements for power, but perhaps again it might be too cumbersome.

If farmers persist in making silage from high-moisture crops, some method should be devised for getting rid of the free juice without having it seep through the walls of the silo. To do this I would envision vertical slots in the wall, say every 4 ft apart and extending from near the top to a trapped drain at the bottom. These slots could be 1/2 inch wide and 3/4 inch deep. It would appear desirable to pre-

vent these slots from becoming ducts for the admission of air, by an air-trap at the outlet. In case the silo is not completely filled it would be a small job to plaster the slots shut near the top level of the silage with wet clay in order to prevent access of air from the top.

Discussion by G. R. Shier

MEMBER A.S.A.E.

MR. WOODWARD'S paper gives us a realistic picture of the place of hay-crop silage in the production and storage of forage crops. In our agricultural-engineering work, there is a real need for standards from specialists in nutrition, biochemistry, and animal management to be used as guides in designing engineering structures and equipment and in planning operations. We are fortunate in having this guide post from outside our engineering field.

We are all familiar with the fact that the present tendency in crop rotations is toward an increase in the acreage of hay and pasture crops. In Ohio, this fact has been an important factor in the use of hay crops for silage. However, we have many farmers who cannot for a variety of reasons use hay-crop silage. They do not have a silo or silage machinery. They cannot feed silage fast enough to prevent spoilage, especially in summer when pastures are short. Steer feeders complain that it produces yellow fat. The trench silo offers a partial solution of these difficulties, and its use is increasing, but on many of our farms the production of hay will remain of great importance. For these farms perhaps the most significant aspects of Mr. Woodward's paper are the statements in regard to the comparative feeding value of good hay and good silage. While there is every reason to improve our techniques for making and preserving hay crops in the silo, we must not neglect the possibilities of improved methods of making hay.

Mr. Woodward has stated that wilting of hay crops to a moisture content of less than 68 per cent will eliminate or reduce many of the problems of storing the crop in silos, such as leakage of juice, need for preservatives, unpleasant odors, and intense structural stresses. He goes further and mentions good quality silage made from alfalfa containing only 31 per cent moisture.

Apparently good silage can be made through a wide range of moisture contents. If the moisture content of the crop is wilted below 60 per cent, there may be a possibility of storing it in specially ventilated mows where the remaining moisture can be removed. The Tennessee Valley Authority and the University of Tennessee have reported considerable success with this method.

R. C. Miller has made observations and obtained data from two farms in Ohio, one of which chopped alfalfa containing as much as 60 per cent moisture into a ventilated mow and made a good bright hay.

It is apparent that we have several definite fields of hay-crop harvesting and storage. High moisture hay silage may be a necessity under certain weather conditions. However, on small and medium-sized farms, hay cutting can be done in the morning on favorable days, wilted in the swath, and placed in the silo or a ventilated mow in the afternoon.

We need to know more about low-moisture content silages with comparisons between them and hay made by the wilting-ventilation method.

Mr. Shier is research agricultural engineer, Ohio Agricultural Experiment Station.

¹Drying hay in the barn and testing its feeding value. Univ. of Tenn. Agr. Expt. Sta. Bul. No. 170. Also J. W. Weaver, Jr. The development of a low-cost hay drier. Agr. Engr. Vol. 18, No. 1 (January 1937); and J. W. Weaver, Jr. and C. E. Wylie. Low-cost hay drying. Agr. Engr. Vol. 20, No. 1 (January 1939).

Equipment, Methods, and Costs of Collecting Farm Crop Residues

By R. B. Gray

MEMBER A.S.A.E.

TIED IN with the work at the new (U.S.D.A.) regional laboratories for research on industrial utilization of farm commodities, there likely will be a certain amount of field work, a portion of which—that to do with the development and economical use of growing and harvesting equipment to furnish the raw material—will fall in the province of agricultural engineers. Existing equipment may be used or altered, or made up in combinations to fit particular requirements.

According to U. S. Department of Agriculture figures, the wheat acreage harvested in 1938 in the United States was more than 70 million, Kansas having the largest acreage or nearly 14½ million acres, North Dakota coming second with nearly 9 million, Oklahoma third with about 5½ million, Nebraska fourth with over 4½ million acres, and so on. On the basis of the conversion figure 1.9 (1.9 lb of straw to 1 lb wheat), there were nearly 56 million tons of wheat straw produced in the United States that year. It is assumed that 25 per cent of this straw could be used advantageously on farms. That means that in 1938 about 14 million tons were so used and about 42 million tons might have been used in industry if conditions had been right. More than ½ million tons was the strawboard mill consumption, leaving a net of some 40 million tons still available for conversion purposes.

STRAW QUALITY REQUIREMENTS OF STRAWBOARD MILLS

As the strawboard industry represents the largest single user of agricultural residues, a practical approach to the collection problem would naturally be to make observations as to methods used and the problems encountered by that industry. Accordingly several trips were made to the field, and contacts were made with strawboard mills and farm-machinery manufacturers. Dr. E. C. Lathrop and Joseph H. Shollenberger of the Northern Regional Research Laboratory made several of these excursions, and I joined them on one three-weeks tour.

From the information at hand it seems that, first of all, a set of specifications for straw to be delivered to the straw mill might well be drawn up somewhat as follows:

- 1 Moisture content—12 to 15 per cent
- 2 Chaff and dirt content—3 per cent or less
- 3 Weed content—0 per cent
- 4 Baled with two wires, placed and tied with care
- 5 Long straw (cut leaving stubble about 4 in long)
- 6 Current year straw, containing no decomposed material
- 7 Standard size bale, 16x18x40 in—compact, weighing approximately 75 lb.

The economic gathering of this straw and putting into suitable shape for transportation is the responsibility of agricultural engineers. Department of Agriculture figures for 1938 show that, of the wheat harvested in the United

States, 49 per cent was combined and 47 per cent handled by the binder-thresher method. In 1938 about 82 per cent of the wheat acreage was harvested with the combine in Kansas and 16 per cent by the binder-thresher method; the balance or 2 per cent was handled in other ways. In North Dakota 23 per cent was harvested by the combine and 70 per cent by the binder-thresher method. In Oklahoma the figures were 70 per cent and 40 per cent, respectively. These statistics all show that there are two general conditions to be met in the collection of straw.

STACK AND COMBINE STRAW HANDLING PROBLEMS

In the binder-thresher method the thresher cylinder and concave are ordinarily fitted with spike teeth which, during the threshing operation break the straw considerably and thereby increase the amount of fine material, or chaff. This chaff is of little or no value to the strawboard mill; in fact, it is a detriment because it absorbs more liquid in the cooking process and has little value for fiber. In other words, it results, according to the processors, in higher chemical consumption than would be the case with straw having a lower chaff content. The straw in the stack may contain as high as 20 per cent chaff by weight. This means extra cost in baling, transportation, and processing, besides removal from the land of a valuable material for improving the soil.

The processor in normal seasons pays around \$6.00 a ton for straw, delivered at the plant. Most of this straw is supplied by a contractor who pays from 50 cents to \$1.00 per ton to the farmer for the straw as it lies in the stack, chaff and all. The difference between what the processor pays and what the farmer gets—approximately \$5.00—is made up of baling costs, amounting to about \$2.50, and transportation costs, amounting to about \$2.00, for distances not exceeding 50 or 60 mi, and profit for the baler. As it now stands, \$1.00 of the \$6.00 paid per ton for the baled straw is for useless chaff which, as stated above, makes for high chemical consumption. The processor could really pay about \$7.00 per ton delivered for clean straw. The farmer could be paid the extra \$1.00 if he could supply clean straw. This would be possible if the thresher were equipped with a device to separate the chaff from the straw. If the farmer could bale the straw himself and deliver it, his income possibly would be still further increased.

Several schemes have been proposed for collecting the straw when the grain is to be harvested by the combine or harvester-thresher method, as follows:

1 Cut the high stubble left by the combine with a mower fitted with a swather attachment and follow with a pick-up baler. However, unless this work is done within a few days after harvesting, weeds or any cover crops, such as clover, will contaminate the straw and add considerable moisture which may cause deterioration.

2 In place of the swather attachment to the mower, a side rake could be used to throw a windrow first from one side and then from the other, the second being thrown as nearly as possible on top of the first windrow. This would be followed by a pick-up baler.

3 Use a mower to cut the straw low, with or without

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a swather attachment, and, by means of a buck rake, push the straw up to a stationary baler.

4 Mount a mower attachment under the combine toward the rear. (It has been stated this attachment would cost around \$100). This would have the advantage of cutting the straw before the weeds could grow and the straw would be fairly free of chaff. Then use a pick-up baler or haul the straw to a stationary baler.

5 Set the cutter bar of the small combine so it will cut the straw close to the ground and, with the aid of a chaff deflector, discharge the clean straw into a pulled baler.

Some objection has been raised to this last proposal for the reason that, with such a large volume of straw going through, considerable grain would be carried over and difficulty would be experienced in cleaning. Some manufacturers state that these difficulties are more fancied than real. Perhaps the design of the separating mechanism could eventually be altered to increase its capacity, if that is found necessary. Straw from the combine, as a rule, does not contain more than 5 per cent chaff, and most of the chaff goes back on the land. Also, the straw in general is not badly broken up in going through the threshing mechanism because of the absence, in most small machines, of the spike-type cylinder. In the minds of some farmers who need straw for bedding, the combine seems to be losing favor, especially under conditions such as existed last season. By increasing the separating capacity the main objection would be overcome, and the farmer then could have some straw and be in a position to sell any surplus.

Estimates of costs for gathering the straw by two methods, based on studies made by different agencies, are as follows:

1 With mower, side rake, and baler—		
Mowing with horses (5-ft mower cutting one acre per hour)	Per ton	Per acre
(Mowing with a tractor-drawn 7-ft mower cutting 2 acres per hour would cost 0.48 per acre)	\$0.45	\$0.60
Raking with side rake (2 horses, 8-ft rake, 2 acres per hour)	0.25	0.30
Baling with stationary baler (600 bales per 10-hr day. This item includes getting straw to the baler)	2.50	1.90
Transportation (from field to mill)	1.75	1.30
Total cost	\$4.95	\$4.10
2 With baler pulled behind combine—		
Baling	1.50	1.10
Transportation (picking up bales in field and hauling to mill)	2.00	1.50
Total cost	\$3.50	\$2.60
Straw yield $\frac{3}{4}$ to 1 ton per acre		

According to U. S. Department of Agriculture figures, the corn acreage harvested for grain in 1938 was nearly 92 million acres. With an average of about $1\frac{1}{2}$ tons of stalks per acre, there would be some 138 million tons of stalks throughout the United States available for industry. However, it would be practicable only to use the stalks from the more concentrated areas. On the basis of 1.5 tons of stalks per acre, approximately 45 million tons of stalks are readily accessible. Of these, it is stated that about half of the weight is in the tops, leaves, and husks, which are good for feed but of no value to the processors.

The gathering of these stalks presents a considerably different problem than the gathering of straw, and one which will need considerable study.

I am suggesting a set of specifications for stalks, as they should be delivered to the processors, as follows:

- 1 Stalks—whole, shredded, or chopped (minimum 4-in lengths)
- 2 Baled tightly in standard size bales—16x18x40 in
- 3 Moisture content—maximum 15 per cent
- 4 Leafy material—less than 3 per cent
- 5 Content of corn kernels and dirt—practically zero.

Ordinarily, corn picking in the corn belt starts about November 1; however, if the stalks are to be used for processing, delayed harvesting might be desirable. As noted above, leaves are not desired and by delaying harvesting a few weeks many of these will have been blown away. Further, as the moisture content of the stalks for storage purposes should be less than 20 per cent, harvesting delayed until early December will permit the moisture content to reach that figure. When picking begins, the stalk moisture content may be as high as 40 or 50 per cent.

There are a number of ways by which cornstalks may be harvested, several of which have been referred to in a bulletin by the Iowa Station¹. Following are costs of some of the methods, as shown in that bulletin:

	Cost per ton
1 Cutting by hand and shocking (1.5 acres per day), including 4 cents per acre for twine	\$1.67
2 Sled harvesting and shocking (4.67 acres per day)—two men, horse, twine, overhead	1.40
3 Corn binder and shocking ($7\frac{3}{4}$ acres per day)—one man, 3 horses, and two extra men for shocking (For total cost of each of the above methods add \$2.50 for baling.)	1.90
4 Special machine developed by Iowa State College, made up of mower, modified hay loader, and baler operating as a unit	5.45
5 Once-over machine (proposed)—would pick corn from standing stalks and then cut stalks with a mechanical knife and pass stalks through shredder head into a trailer baler. During the shredding process a blower attachment mounted at the discharge would blow out the leaves and light material—estimated cost	6.00

To each of the above totals should be added about \$2.00 per ton for hauling, probably an average price for a distance of from 20 to 30 mi.

Farmers have been getting around \$8.00 per ton for stalks delivered at the processing plant. The method used in gathering the material determines whether or not the farmer receives any profit.

It might be mentioned at this point that there would be an advantage in cutting the stalks low. Experiments have shown that removing with the stalks the six or eight inches of stubble ordinarily left when cutting corn for the silo, increases the yield of stalks some 5 to 10 per cent. In some regions this low cutting would be a factor in control of the European corn borer. While there may be some dirt on the lower parts of the stalks, most of this would be jarred loose in shredding.

Undoubtedly many other, and perhaps better, ideas may develop in connection with gathering straws and stalks. It is believed, however, that the points I have mentioned will provoke thought along this line, so that a unified program can be worked out. The states concerned will all benefit by this program in increased income to the farmer. Many points, including agronomic and soils considerations, must yet be settled.

As you may know, a committee has been appointed in the American Society of Agricultural Engineers to deal with the subject of collecting crop residues, which would be glad to act as a clearing house for any ideas.

¹Iowa Agricultural Experiment Station Bulletin No. 322, or Iowa Engineering Experiment Station Bulletin No. 3.

Application of the Erosion Equation to Strip Crop Planning

By R. W. Gerdel and R. E. Allen

SATISFACTORY strip cropping as a soil conserving practice has been impeded by the lack of available data for soil losses on a wide range of land slope, watershed length, and soil types. Most of such data available are the result of a few experiments conducted on controlled plots of relatively short length, without contributing watersheds above them. Frequently the degree of land slope and amount of previous erosion on such plots has been produced artificially by manipulation of the surface soil. The influence of such practices on soil losses has produced data, which, though of value in measuring soil and water losses, are not always directly applicable in formulation of practical conservation plans.

Studies have been made since 1936 in the Ohio Valley Region (an administrative unit of the Soil Conservation Service comprising the states of Ohio, Indiana, Michigan, Kentucky, and Tennessee), under field conditions, of the relationship between soil loss from cultivated strips and such factors as land slope, watershed length, divergence from the contour, soil type, land use on the contributing watershed, and degree of previous erosion. The results of these studies, a portion of which have been published^{1, 2, 3*}, have provided pertinent information upon which to base plans for future strip cropping in a large portion of the Ohio Valley and adjacent regions having similar physical and pedological factors.

Further interpretation of these data, along with addi-

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*Superscript figures refer to correspondingly numbered references in the bibliography appended to this paper.

tional data obtained in 1939, indicated that the influence of land slope and watershed length on soil losses from cultivated strips on a considerable number of soil types could be expressed logarithmically, and that an equation could be derived which might permit interpolation of soil losses (as affected by degree of slope and length of watershed) not directly obtained in this study.

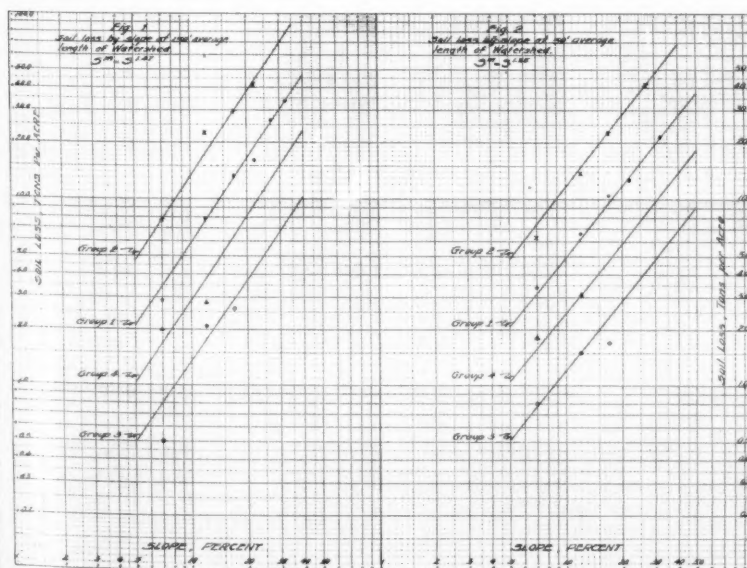
Development of Erosion Equation. Field measurements of soil losses from approximately 150,000 linear feet of cultivated strips in the Ohio Valley Region on soils which previously had been grouped according to the relationship between soil loss and subsoil characteristics^{2, 3} are presented in Table 1. These data include approximately 300 samples, each consisting of one or more miniature watersheds. The procedure used in collecting and analyzing these data has been presented in another publication³. However, the analysis of the data in this paper is based solely upon strips varying in width from 28 to 84 ft and having watersheds either entirely strip cropped, or entirely under cultivation with approximately one-half the watershed in row crops and one-half in meadow or rotation pasture. In grouping the data by land slope, 4 per cent class intervals were used. Hence, the land slope class of 12 per cent represents all strips having a land slope on the watershed above the strip of 10 to 14 per cent, inclusive. The length of watershed, as measured from the top of the strip to the farthest point on the slope contributing runoff to the strip, was grouped by 100-ft class intervals. Under such grouping the 150-ft length of watershed class contained all strip samples having watershed lengths of 100 to 199 ft, inclusive. Grouping of soil losses by such wide class intervals was necessary, since considerable variation in land slope and length of watershed occurred within the samples from even the smaller watersheds studied.

Based upon an analysis of plot studies, Zingg⁴ has presented the erosion equation,

$$X = CS^m L^n$$

in which X represents total soil loss; C is a constant of variation; S is the land slope; L is the length of slope; ^m is an exponent of land slope, and ⁿ is an exponent of length of slope. He found that under the conditions studied, the values for ^m and ⁿ were 1.4 and 1.6, respectively.

Logarithmic plotting of the measured soil losses obtained from the strip cropping studies (Table 1) for the 50 and 150-ft lengths of watershed (Figs. 1 and 2) indicates that there is apparently a similar relationship between length of watershed and steepness of slope to soil losses from cultivated strips on all soil groups. The exponent



for steepness of slope for any definite length of watershed is the same for all soil groups, and a soil group erodibility factor will determine the difference in soil losses between groups.

An analysis of the logarithmic plotted data for the soils in group 1 (Fig. 3) and of the exponent for land slope (Fig. 4) indicates that neither length of watershed nor steepness of slope may be considered independently in determining the relationship between these factors and soil loss from cultivated strips on relatively long watersheds. From Figs. 1, 2, and 3 it appears that the erosion equation for soil loss from cultivated strips may be expressed as

$$X = C.S^m$$

in which X represents soil loss in tons per acre from any given cultivated strip, C a constant of variation for soil group or soil type based upon erodibility, S is slope of the watershed in per cent, and m is an exponent which varies by length of watershed.

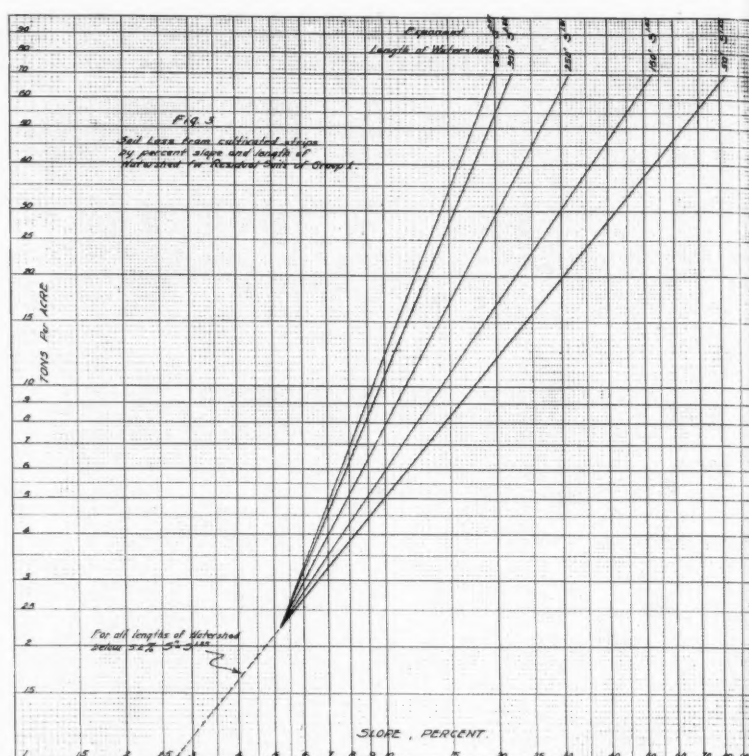
Plotting the values for m against length of watershed (Fig. 4) produced a tangent curve with the center of moment about the values $m = 1.91$; length = 250 ft. The equation for this curve is

$$m = 1.91 + .61 \left[\arctan \left(\frac{L - 250}{100} \right) \right]$$

In this equation all numerical values remain constant and only the length of the watershed need be inserted for the value L to secure the exponential value m to be used with the land slope value S in the basic equation.

The fact that the logarithmic curves for soil losses at various lengths of slope all converge at 5.2 per cent slope may only indicate that soil losses from cultivated strips on the residual and glacial soils included in this study and on slopes of less than 5 per cent were too small to be measured accurately.

For land slopes of less than 5.2 per cent the curve for the 50-ft length of watershed was projected to the left (Fig. 3) as shown by the broken line, and calculated losses



for strips on all lengths of watershed with slopes of less than 5.2 per cent are based on this curve having an exponent of 1.25.

On certain loessial soils of southern Indiana, Kentucky, and Tennessee, and the prairie type of Brookston of northwestern Indiana, large soil losses have been measured from cultivated strips on slopes of 2 to 4 per cent when watershed length exceeded 700 ft. Insufficient data are available to indicate whether a large value for the soil group erodibility factor, a larger value for the exponent m , or a different point of convergence will adjust the erosion equation to such soils.

Field data are not available for watershed lengths greater than 450 ft above the top edge of the cultivated strip. Until further data are obtained, the use of the equation to extra-

TABLE 1. COMPARISON OF AVERAGE MEASURED SOIL LOSS FROM CULTIVATED STRIPS WITH THEORETICAL LOSS CALCULATED BY USE OF THE EROSION EQUATION^a

Soil Group	Per cent slope ^c	Soil loss in tons per acre for watershed lengths of ^b :									
		50 ft		150 ft		250 ft		350 ft		450 ft	
		Calc	Meas	Calc	Meas	Calc	Meas	Calc	Meas	Calc	Meas
Group 1. Residual soils with light-textured or permeable subsoils	2	0.7	0.2	0.7	1.1	0.7					
	7	3.2	3.4	3.5	2.9	3.9					
	12	6.3	6.6	7.7	7.9	11.1	12.7	16.3	12.9	19.3	3.4
	17	9.7	10.5	13.0	13.3	21.5	26.0	37.0	35.4	47.0	47.2
	22	13.3	12.7	19.0	16.1	35.5	37.1	68.0	64.8		
	27	17.3		25.6	26.3	52.4	52.8				
	32	21.4	21.2	33.2	33.4	72.2	76.5				
Group 2. Residual soils with compact or impermeable subsoils	7	7.5	6.4	8.1	7.9	9.3					
	12	16.0	13.9	17.8	22.4	26.0	29.1				
	17	22.5	22.3	30.2	29.5	50.0					
	22	30.8		44.0	42.0	82.4					
	27	39.6	41.6	59.4		121.6	116.7				
Group 3. Glacial soils with light-textured or permeable subsoils	2	0.2	0.0	0.2	0.0	0.2					
	7	0.7	0.8	0.8	0.5	0.9	1.1				
	12	1.5	1.5	1.7	2.1	2.5	2.7				
	17	2.1	1.7	2.9	2.6	4.5	3.2				
Group 4. Glacial soils with compact or impermeable subsoils	2	0.3	0.0	0.3	0.1	0.3	0.0				
	7	1.6	1.8	1.7	2.0	1.9	1.6				
	12	3.1	3.1	3.8	2.7	5.5	6.8				

^aCalculated losses interpolated from logarithmic curve for erosion equation.

^bLength of watershed is average for class by 100-ft intervals.

^cPer cent slope classes are ± 2 per cent, i.e., 12 per cent slope class includes all slopes from 10 to 14 per cent.

TABLE 2. CONSTANT OF VARIATIONS FOR SOILS IN GROUP 1

Slope length, ft	Constant of variation, C
50	0.282
150	0.202
250	0.088
350	0.048
450	0.033

polate the exponent m for watersheds of greater length is not advised.

In a previous publication³ it was shown that the soil types included in this study could be assigned to definite erosion groups according to their geological origin and sub-soil characteristics.

The constant of variation, C (Table 2 and Fig. 5), which varies with length of watershed, is further modified by the erodibility factor for each soil group. This erosion factor was determined by assigning an arbitrary value of 1 to soil group 1, and calculating the soil-loss ratio for each of the other three groups from the vertical position of the curves in Figs. 1 and 2.

The soil groups and their erodibility factors are as follows:

Group 1. (Erodibility factor = 1.00) Residual soils with light-textured or permeable subsoils: Muskingum silt loam, Muskingum silty clay loam, Westmoreland silt loam, Westmoreland silty clay loam, Hagerstown silt loam, and Bedford silt loam.

Group 2. (Erodibility factor = 2.32) Residual soils with moderate to heavy-textured or compact subsoils: Wellston silt loam, Tilsit silt loam, Coolville silt loam, Meigs silt loam, Meigs silty clay loam, Belmont silty clay loams, and Upshur clay loam.

Group 3. (Erodibility factor = 0.22) Glacial soils with light-textured or permeable subsoils: Wooster silt loam, Canfield silt loam, Chenango silt loam, Chenango loam, and Braceville silt loam.

Group 4. (Erodibility factor = 0.50) Glacial soils with moderate to heavy-textured or compact subsoils: Rittman silt loam, Ellsworth silt loam, Cardington silt loam, and Miami silt loam.

A satisfactory equation, permitting the direct calculation of values for C , has not been derived. The constant of variation may be determined by multiplying the value obtained for any length of watershed from the graph (Fig. 5) by the appropriate soil-group erodibility factor.

Discussion. Calculation of theoretical soil losses from cultivated strips on different soil types with different lengths of watershed above the strip and different land slopes have been made according to the equation $X = C.S^m$ with the value for the exponent.

$$m = 1.91 + .61 \left[\arctan \left(\frac{L - 250}{100} \right) \right]$$

and with L in the equation for m being the length of the watershed above the strip.

The values are tabulated in Table 1, along with the average measured soil losses for the same slope and length of watershed class intervals. Satisfactory agreement between measured losses and the loss determined by use of the erosion equation has been attained.

The erosion equation can be used on the soil types included in this study to determine the expected soil loss from individual cultivated strips in either a present or contemplated strip-cropped field. By assuming an arbitrary maximum allowable soil loss, the spacing of diversion ditches on long, strip-cropped watersheds may also be determined.

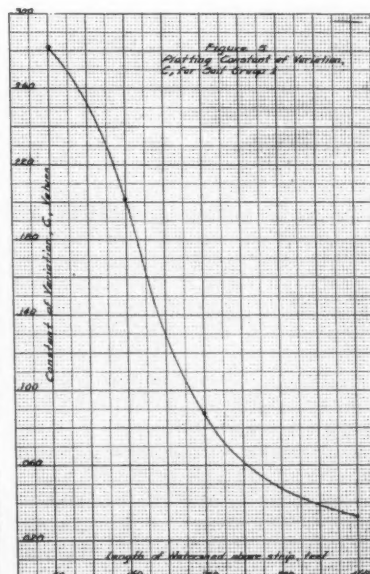
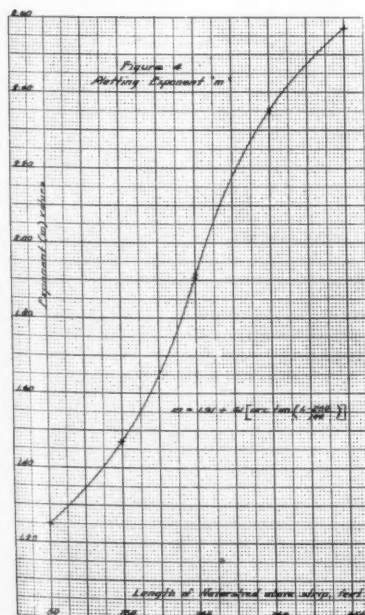
Climatic variations from year to year will influence the soil losses from cultivated strips. The data on which this equation was based included only those which were obtained during the growing season of 1938. Data obtained from similar studies in 1937 indicated that soil losses from cultivated strips in that year were approximately 50 per cent greater than in 1938. The 1939 losses were approximately 30 per cent less than in 1938. However, variations in climatic conditions from year to year appear to have exerted less influence on the changes in quantity of soil lost from cultivated strips than has been exerted by the development of a complete conservation program on a farm³. The use of more lime, fertilizer, and adapted legume-grass mixtures in the meadows has exerted a greater influence on soil loss than has the small change in climatic conditions over the period of years in which this study was conducted.

The determination of probable soil losses from strips by use of the erosion equation involves considerable calculation and reference to prepared tables of tangents and logarithms. For practical purposes, soil losses from cultivated strips may be determined by the use of a graph (Fig. 3) and a supplementary table of soil group erodibility factors.

SUMMARY

An erosion equation is presented by which the expected soil loss from any given cultivated strip in a strip cropped field may be calculated for a large number of soil types in the Ohio Valley Region.

Use of this equation, and selection of arbitrary maximum soil losses, permits the de- (Continued on page 64)



Crops and Dams Protect a Watershed

By Emerson Wolfe

JUNIOR A.S.A.E.

SOIL-SAVING crops and detention dams have been made the primary defense against floods and erosion in the McGregor watershed bordering the Mississippi River in northeastern Iowa, where conservation is vital to farmers and townspeople alike.

McGregor, situated in the narrow outlet of the 2,250-acre watershed, has long been beset by damaging floods resulting from runoff from the steep hills in the drainage area above. Each heavy rainstorm brought swollen streams of water rushing on the town to leave litter and destruction in their wake.

Farmers throughout the watershed suffered equally with the townspeople. Each rainstorm washed thousands of tons of soil from their fields, cut large gullies in their waterways, and deposited the accumulation of silt and rock in the streets of McGregor, or in the channel of the Mississippi River. As the surface soil was removed, yields declined or were scarcely maintained at the expense of applying commercial fertilizers, lime, and manure. Rural incomes decreased and consequent reduction in purchasing power was reflected in the waning prosperity of the town.

The fact that a flood-free period of 24 years elapsed between the floods of 1866 and 1890 indicates that the runoff coefficient of the watershed was less at that time. It appears that a close relationship exists between the depletion of soil and vegetative cover of the land in the watershed and the frequency and severity of flood damage. This emphasizes the importance of considering the future land use pattern of the drainage basin when devising a program of surface runoff control.

The, 2,250-acre fan-shaped McGregor watershed is composed of several separate drainages, which converge just above the town. The upland in the outer reaches of the area rises to a height of 500 ft above the river, with no point more than 2.7 mi distant from the outlet. Long, narrow, hog-back ridges which break rapidly into steep rocky slopes and then flatten into narrow drainageways, are characteristic of the general topography.

Presented before the Soil and Water Conservation Division at the fall meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 6, 1940. Author: Associate agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture.

Almost every feature of the watershed is conducive to a rapid concentration of runoff from short intense rains lasting 30 min or more. Originally the heavy growth of timber which covered the entire area was sufficient protection against excessive runoff from summer storms. Nature was in balance.

During a period of 75 to 100 years the cultivated land in the area lost approximately 60 per cent of its topsoil through erosion. The remaining mixture of subsoil and topsoil erodes more easily and lacks the water-holding capacity of the original surface layer.

In 1935, 44 per cent of the area was used for pasture, 34 per cent for cultivation, and 9 per cent for woodland. The pastures occupied the rough, sparsely timbered hillsides, and their overgrazed condition offered little protection against runoff and erosion. Cultivated fields on slopes ranging up to 25 per cent were too frequently devoted to clean-tilled crops. State-owned timberland adjacent to the town comprised the bulk of the ungrazed woodland in the area.

A committee of businessmen from McGregor and a committee of farmers were chosen to meet with technicians of the Soil Conservation Service to study and recommend solutions to the problems. It was immediately agreed that an extensive soil and water conservation program should be initiated on the agricultural land within the drainage area, as the first fundamental step in any program that might be adopted after further study could be made.

The majority of the farmers in the area expressed a willingness and desire to adopt practices that would protect their soil resources, conserve the rainfall for crop production, and at the same time offer a measure of protection to the town. Thirty-two of the forty landowners in the area entered into 5-year cooperative agreements with the Soil Conservation Service. These agreements outlined complete conservation plans for the farm and made it possible for the Service to assist the farmer in putting his new program into effect. Every possible effort was made to improve land use, to increase the fertility and absorptive capacity of the soil, and to reduce erosion. Contour cultivation, strip cropping, terracing, diversion ditches, pasture furrows, and other



(Left) Aerial view of McGregor watershed, illustrating topography and drainage. Entire watershed drains through town of McGregor, Iowa, on the Mississippi River. (Right) One of three detention reservoirs built to prevent severe flood damage to town of McGregor. This structure checks floodwaters from 385 acres of rough farm land which are protected against erosion with vegetation, terraces, and contour farming methods



(Left) A farm field on the watershed before soil conserving practices started, showing evidence of loss of top soil. (Right) Terraces, strip cropping, contour farming, and other erosion control measures are now used to keep soil and water on farm fields in the area. Most of the farmers are cooperating

supporting practices were used to hold the rain where it fell or to retard its movement down the slopes.

As this phase of the work progressed, studies were made of rainfall frequencies, expected rates of runoff, and the capacity of the disposal system. Since no reliable rainfall records were obtained during past floods, and flows through the sewers and streets were invariably obstructed by the accumulation of debris, it was impossible to correlate the two in determining a runoff coefficient of the watershed. The problem was further complicated by the inadequacy of runoff data that could be obtained from other areas of comparable physical conditions and size. For these reasons, estimates were based on the rational method of computing runoff, which employs the formula $Q = CIA$, and were checked in so far as possible by observational records of previous floods.

Investigations made in this manner indicated that an intensive conservation program on the agricultural lands might result in the reduction of the frequency of minor floods from once in 2 years to once in 4 or 5 years. There would be also a reduction in the magnitude of the more severe floods of less frequent occurrence, but this effect would be expected to diminish as the intensity of the rain increased. The difficulty of securing 100 per cent farmer participation and of approaching ideal land use without seriously reducing farm income, of course, were factors that limited the effectiveness of this effort.

The need for immediate protection in addition to the land use program, and the possible reconstruction of the storm sewer at some future time, led to an investigation of suitable sites for detention reservoirs in the main drainageways above the town. Limiting factors were the existence of highways and residences along the valley bottoms and the steep gradient of drainage courses. After numerous surveys had been made, four locations were found where reasonably adequate storage basins could be obtained. Unfortunately, the site that offered the greatest natural advantage for impounding water was eliminated from further consideration because it involved the removal of three residences and the relocation of three-fourths of a mile of paved highway. In the final analysis, reservoirs located in Walton Hollow, West McGregor, and Siegele Hollow, with drainage areas of 385, 415, and 100 acres, respectively, appeared worthy of detailed study.

Earth dams with reinforced concrete spillways seemed the most practical type of construction. Since the entire storage capacity of the reservoirs was needed for runoff detention during periods of intense rainfall, it was determined to provide each dam with two separate spillways. A small conduit was designed to regulate the flow through the dam to approximately one-half inch of runoff per hour from the watershed. This tube, built on the order of a road

culvert, opens into the bottom of the reservoir to prevent any impoundage, except when the rate of runoff from the drainage area exceeds its discharge capacity. A large emergency spillway of the drop-inlet type was also provided to guarantee the safe operation of the dam under flood conditions of rare occurrence.

The storage capacities of the reservoirs were made as large as seemed practical under existing conditions. As built, they should accommodate the accrued runoff from a rain of 50-year frequency, with due consideration being given to the effect of vegetative cover and mechanical measures in use on the drainage areas. Runoff data obtained at the Soil Conservation Experiment Station at La Crosse, Wisconsin, were of assistance in estimating the rates and amounts of runoff to expect from areas devoted to the various phases of land use.

Since these reservoirs would be located directly above a small densely-populated town, the emergency spillways needed to be large to avoid possible disaster in the event of an unusual flood. For this reason they were designed to discharge approximately 50 per cent more than the estimated maximum runoff that had occurred in the past, or about 6 sec-ft per acre of drainage area.

Because of the debris usually carried down by the floodwater, trash racks in the stream channels above the reservoirs and screens over the spillway inlets were considered necessary. Grids made of railroad rails and reinforcing bars and anchored by concrete abutments were included in the design.

Provision was also made for protecting the spillway outlets. These designs were not elaborate but are adequate to dissipate the flow from the small discharge conduits, and to prevent damage to the dam should the emergency spillways come into use.

All dams were designed with 30-ft top and 3:1 slopes on both upstream and downstream sides. No core walls were provided. General specifications of the three dams and reservoirs are shown in Table 1.

TABLE 1. GENERAL SPECIFICATIONS OF DAMS AND RESERVOIRS

	Walton Hollow reservoir	West McGregor reservoir	Siegele Hollow reservoir	Total
Drainage area, acres	385	415	100	900
Normal storage capacity, acre-feet	39	47	16	102
Maximum storage capacity, acre-feet	76	82	24	182
Normal discharge capacity, second-feet	194	260	44	498
Maximum discharge capacity, second-feet	2200	2330	678	5208
Height of dam, feet	35	35.5	25	
Cubic yards of fill	43,000	42,500	23,865	109,365

Construction of the detention reservoirs and trash screens was begun in the late fall of 1937 and continued seasonally until their completion in August 1939.

Labor for construction work was supplied principally by the CCC camp at McGregor. WPA laborers and local skilled workmen were employed to operate equipment and to assist in other important phases of the work. During the 1938 season, a shovel and dump trucks were used for constructing the rolled earth fills of the dams. Job conditions were not entirely favorable for the operation of these units, and a change to tractor-drawn wheeled scrapers for earth moving in the 1939 season proved much more successful.

Splendid cooperation was extended to the town by other public agencies. The Iowa Highway Department relocated one-half mile of Highway 340 two years in advance of their construction schedule to permit the building of the Walton Hollow dam. This highway, now completed through the drainage area of the reservoir, was designed to limit bank and ditch erosion to a minimum. The board of supervisors of Clayton County made possible the relocation of a section of county road over the West McGregor dam. The Iowa Conservation Commission had already purchased about 132 acres of land adjacent to the town for retirement to timber or park areas.

FUTURE FINISHING TOUCHES FOR THE PROTECTION OF THIS WATERSHED

At the present time the essential provisions of the co-ordinated program have been carried out. Cultivated land in the watershed has been reduced from 34 per cent to 25 per cent and is now largely protected by improved crop rotations, strip cropping, terracing, and contour tillage. Permanent meadow and protected timber areas have increased accordingly. Although the land-use phase of the program has developed satisfactorily, further improvement is desirable. The basis for future work has been provided, and it is logical to expect a more widespread adoption of practices each year as farmers become more conservation-minded. The town of McGregor has purchased 54 acres of timberland in accordance with the terms of the agreement and plans to buy more as it becomes available. The three detention reservoirs are ready to function, if their protection is needed. Minor sewer alterations have been made and the town is prepared to make permanent improvements according to engineering plans as major repairs become necessary.

Two problems remain without an immediate and satisfactory solution, namely, (1) grazing of steep timbered hillsides and (2) the movement of rock in the larger stream channels. Both are dependent on land ownership and land use for their solution, although the latter may require some additional engineering work. An extensive land purchase program in the McGregor watershed may be found desirable at some future time.

It is important to realize just what protection will be afforded to the town of McGregor by this program. In what may be termed normal floods, the reservoirs will not have their emergency spillways brought into use, and the rate of runoff from the watershed will be reduced very nearly in the proportion of the area contributory to the storage basins, or 40 per cent. Runoff coming from the remaining 60 per cent of the drainage area should not exceed the capacity of the storm sewer in sufficient amount to cause serious damage. The ratio between runoff and sewer capacity should improve as the land use and sewer reconstruction programs proceed.

If a storm of great severity should occur, however, it may fill the reservoirs before subsiding and the rate of discharge may not be reduced. The total result in such a

case would be to postpone and shorten the flood peak. To design for flood-peak reduction would not be entirely practical.

The first flood recorded in McGregor occurred in 1866, but was not serious. Other damaging floods occurred in 1890, 1896, 1908, 1916, 1924, 1932, and 1934. Minor floods of less serious consequence recently have occurred on the average of once every two years.

Records show that the town spent \$72,000 for cleaning streets and repairing sewers during the 29 year period from 1908 to 1937. Private losses during this same time have been estimated by a few of the older citizens to be in excess of \$200,000. Municipal expenditures of \$9,300 and private losses of \$45,000 resulted from floods during the five-year period from 1932 to 1937. The total average annual loss for the 29 year period was \$9,345 as compared with \$10,840 for the five-year period.

A 5-in rain in 12 hr July 26, 1940, gave the runoff control measures at McGregor their first test. The rain exceeded the 50-yr frequency for an 8-hr period and caused record floods outside the McGregor project. However, it is expected that record rainfall intensities for periods varying from 30 min to 2 hr will be more critical than the storm of July 26. County officials estimated the damage to the county road system at \$50,000 and damage to railroad tracks in the county was estimated at \$10,000.

The story in the McGregor project was one of control from ridge top to the Mississippi. Practically no erosion occurred on terraced or strip-cropped fields, and damage was surprisingly slight on cultivated fields with contour tillage as the only protection. Erosion on cornfields without control measures was moderate to severe. Although the three detention reservoirs had only a small portion of their capacity used, they held back the flood waters sufficiently to prevent any damage to McGregor. Storm sewers in the town were only about three-fourths full. Trash screens above the reservoirs held back all large rocks and debris which formerly had clogged the storm sewers and streets. The cost of cleaning the screens after the storm was surprisingly small.

Observations made during the storm indicated that the performance of the various phases of the program was in close agreement with expected results.

Application of the Erosion Equation to Strip Crop Planning

(Continued from page 61)

termination of placement of diversion ditches on long slopes which are to be strip cropped.

It is probable that this erosion equation, with only slight modification, can be applied to a considerable area of the country.

For practical use, suitable charts or tables may be prepared from the basic equation, in order to avoid complicated calculations in the field.

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EDITOR'S NOTE: The author has offered to furnish clear ozalid prints of the charts used with this paper, in full scale to readers of AGRICULTURAL ENGINEERING who are interested. Address requests to R. W. Gerdell, U. S. Soil Conservation Service, Dayton, Ohio.

Power Alcohol in Tractors and Farm Engines

By E. L. Barger

MEMBER A.S.A.E.

THIS paper reports results of tests to determine some of the physical properties of alcohol blends with tractor fuels, and performance characteristics of farm engines operating on alcohol blends.

Power alcohol as used herein is ethyl alcohol, anhydrous, produced and denatured for use as a motor fuel. It was purchased at 25 cents per gallon but is no longer available at that price. The plant which produced it has discontinued operation. Twenty-five cents is used, however, as a base alcohol price from which power costs are calculated. The following discussion is a brief interpretation of the data. It is suggested that the tables and figures be studied carefully.

Physical Properties. Table 1 gives some physical properties of alcohol, third-grade (unleaded) gasoline, distillate, and blends of these fuels. All blends were propor-

tioned by weight. The A.P.I. (American Petroleum Institute) gravity of alcohol was 46.0 deg (specific gravity, 0.7972). This is about the same as kerosene, slightly higher than distillate, which was 39.5 deg (specific gravity, 0.8272), and lower than the gasoline which was 62.8 deg (specific gravity, 0.7283). As shown in the weight-per-gallon column, the addition of alcohol to gasoline increases its weight but decreases that of distillate slightly. The costs per gallon of alcohol, gasoline, and distillate were 25.0, 10.0, and 7.2 cents, respectively. Costs of blends of these carry a proportionate part of the cost of each. Heat per pound (high) of alcohol was 13,082 Btu. Gasoline and distillate had (high) heat values of 20,463 and 19,772 Btu per pound, respectively. Due to the low heat content of alcohol, which is 67.5 per cent of that of gasoline, blending it with petroleum fuels lowers their heat value, as

TABLE 1. PHYSICAL PROPERTIES OF GASOLINE-ALCOHOL AND DISTILLATE-ALCOHOL BLENDS

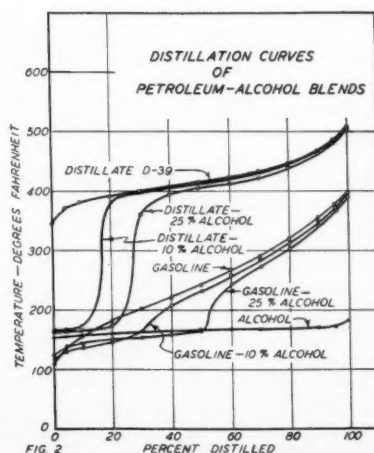
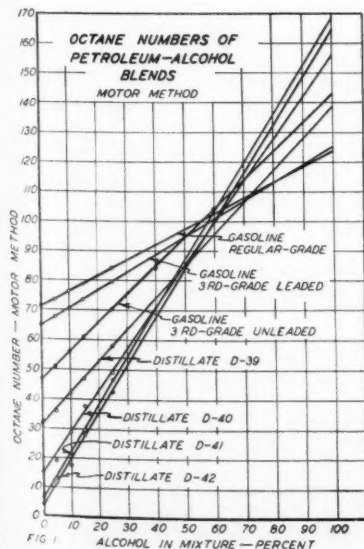
Fuel	Per cent alcohol by weight	A.P.I. gravity	Weight per gal, lb	Cost per gal, cents	Heat per lb Btu (high)	Heat per gal Btu (high)	Btu per one cent	Flash* temp, deg F
Alcohol	100	46.0	6.637	25.00	13,082	86,825	3,473	25.0
Gasoline, 3rd grade	0	62.8	6.062	10.00	20,463	124,047	12,405	—
" " "	5	62.3	6.078	10.75	20,094	122,133	11,361	—
" " "	10	61.7	6.097	11.50	19,725	120,263	10,458	—
" " "	15	60.9	6.122	12.25	19,356	118,497	9,673	—
" " "	25	59.5	6.167	13.75	18,618	114,817	8,350	—
Distillate, D-39	0	39.5	6.888	7.20	19,772	136,189	18,915	126.5
" " "	5	39.9	6.874	8.09	19,437	133,610	16,515	56.5
" " "	10	40.2	6.862	8.98	19,103	131,085	14,597	51.0
" " "	15	40.6	6.846	9.87	18,768	128,486	13,018	48.5
" " "	25	41.0	6.830	11.65	18,099	125,426	10,766	40.0

*Tag. closed cup.

A paper presented before the Power and Machinery Division at the fall meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 3, 1940. Contribution No. 97 of the agricultural engineering department, Kansas Engineering Experiment Station. Author: Associate professor of agricultural engineering, Kansas State College.

TABLE 2. OCTANE NUMBERS OF PETROLEUM FUEL-ALCOHOL BLENDS (MOTOR METHOD)

Fuel	Alcohol in blend, per cent by weight				
	0	5	10	15	25
Gasoline, regular grade	71.0	73.5	75.9	78.7	84.1
Gasoline, third grade, leaded	64.6	67.5	70.6	73.1	79.4
Gasoline, third grade, unleaded	46.5	51.0	55.6	61.0	70.1
Distillate, D-39	31.5	35.7	41.7	46.9	57.9
Distillate, D-40	14.1	18.9	28.7	37.5	48.7
Distillate, D-41	5.8	12.9	21.7	29.1	42.1
Distillate, D-42	4.3	11.1	17.5	28.3	47.1



shown by the columns headed "heat per pound" and "heat per gallon". The column headed "Btu per one-cent fuel investment" shows that about 3.5 times as many heat units were obtained in gasoline and 5.5 times as many in distillate as were obtainable in alcohol per unit cost. This is a considerable handicap for alcohol to overcome. The Tag, closed cup flash temperatures in the last column of Table 1 show the effect of alcohol of lowering the flash temperatures of distillate.

Octane Numbers. The high anti-knock value of alcohol is its chief asset as a motor fuel. This has been recognized for some time, but octane numbers of the blends or the actual

antiknock blending values of alcohol have not been available, particularly for low-octane fuels. Table 2 and Fig. 1 give results of tests on three grades of gasoline, and distillate of four different octane values ranging from 4.3 to 31.5, and 5, 10, 15, and 25 per cent blends of alcohol with those fuels. A straight-line relationship exists between the percentages of alcohol commonly used in a blend and its octane number. This relationship is shown in Fig. 1. The blending value of alcohol is higher in the low-octane fuels and lower in the high-octane fuels. By prolonging the curves to the 100 per cent alcohol point, it is shown that alcohol has an octane blending value ranging from 123 to 170. An average octane blending value appears to be about 145. Octane tests were made on 40 to 60 per cent blends in third-grade unleaded gasoline that gave 84.0 and 103.8, respectively, and these are shown as points on Fig. 1. It is interesting that a 60 per cent admixture of alcohol with any fuel of from approximately zero to 70 octane value made a 100 octane fuel.

Distillation Characteristics. Distillation curves of gasoline, distillate, and alcohol, and blends of them are shown in Fig. 2. Alcohol being chemically pure, should have one boiling temperature (78.5 C or 173.3 F) and a straight-line distillation curve. The A.S.T.M. distillation curve for alcohol shows a slight increase in distillation temperature as the 100 per cent point is approached and a slight turn up at the end which is probably due to the denaturant. Alcohol makes a more volatile fuel and lowers the distillation curves. Gasoline-alcohol curves are lower than either the gasoline or alcohol curve over a part of the distillation range, but this is not so with the distillate-alcohol mixtures. The increased volatility of alcohol-distillate mixtures gave somewhat better part-load operation and better idling than straight distillate fuel.

Separation Temperatures. The separation temperatures of alcohol-gasoline blends have been studied rather extensively. The presence of water has a marked effect of raising the temperature at which the two fuels will separate. Water-free gasoline blended with anhydrous alcohol will not separate except at very low temperatures. Christensen and others¹ report temperatures as low as -60 C (-76 F). Table 3 gives the separation temperatures of anhydrous alcohol blended with four different tractor distillates. The separation temperatures bear a close relationship to the octane values of the distillates, due no doubt to a greater solubility of alcohol in unsaturated and open chain hydrocarbons which are less susceptible to detonation. A 32.5 octane distillate blended with 25 per cent alcohol separated at 15.3 F, while a 4.3 octane distillate-25 per cent alcohol

TABLE 3. DISTILLATE-ALCOHOL BLEND SEPARATION TEMPERATURES (ANHYDROUS ALCOHOL)

Fuel	Octane No. of distillate	Separation temperatures, deg F			
		5% blend	10% blend	15% blend	25% blend
Distillate (D-39)	31.5	11.2	16.9	17.3	15.3
Distillate (D-40)	14.1	19.0	41.5	54.0	58.5
Distillate (D-41)	5.8	17.1	44.5	54.5	59.2
Distillate (D-42)	4.3	23.9	40.0	60.0	75.0

blend separated at 75.0 F. It is apparent that the separation problem would be more serious with alcohol-distillate blends than with alcohol-gasoline blends.

Field Tests. Two tractors were used in field tests, plowing with a two-bottom, 14-in plow. The engines of the two tractors had the following specifications: No. 1, four-cylinder vertical, 1300 rpm, 4-in bore, 4-in stroke, 5 to 1 compression ratio, and manifolding regularly furnished for burning gasoline. No. 2, two-cylinder horizontal, 975 rpm, 5 1/2-in bore, 6 3/4-in stroke, 3.9 to 1 compression ratio and manifolding for handling distillate. A 46.5 octane, unleaded third-grade gasoline and 10 and 25 per cent blends were used in the plowing tests. The carburetors were adjusted for maximum power. This required in each case a slightly greater carburetor opening for the blends. Table 4 gives the results of these tests. Some detonation occurred with tractor No. 1 on gasoline alone, otherwise the performance of both tractors was good on all fuels. The fuel consumption in both pounds per acre and gallons per acre was greater with the alcohol blends. The fuel cost per acre was materially increased when alcohol was used.

Tractor Brake Tests. Variable-load, constant-speed belt horsepower tests were run on three tractors burning third-grade unleaded gasoline of 46.5 octane number and 10 and 25 per cent alcohol blends. Tractors No. 1 and No. 2 were described above under field tests. Tractor No. 3 had a four-cylinder, vertical engine, 1650 rpm, 3 3/8-in bore, 4 1/4-in stroke, 4.5 to 1 compression ratio and an adjustable manifold for heat regulation. A cold setting was used. All tests were run on maximum power carburetor settings.

Fig. 3 shows results of the brake tests on tractor No. 1. The compression ratio of 5 to 1 was a little too high for 46.5 octane gasoline and detonation became a limiting factor at heavy loads. The maximum power developed was greater and thermal efficiency and work per gallon were higher at maximum load runs with the alcohol blends due to their higher antiknock value. With the exception of maximum load tests, the work per gallon was higher and the specific fuel consumption was lower with gasoline than with the alcohol blends. There was some tendency for the alcohol blends to give thermal efficiencies equal to or above gasoline. The fuel costs in cents per horsepower-hour were consistently lower with gasoline.

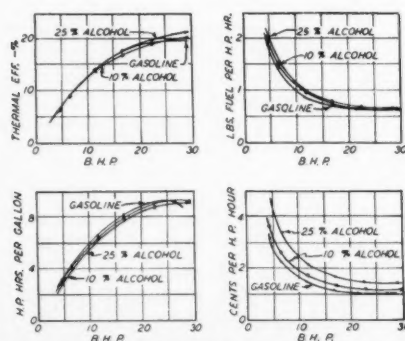


FIG. 3 GASOLINE-ALCOHOL BLENDS IN TRACTOR NO. 1 1300 R.P.M., 500 TO 1 C.R., 46.5 OCTANE THIRD GRADE GASOLINE

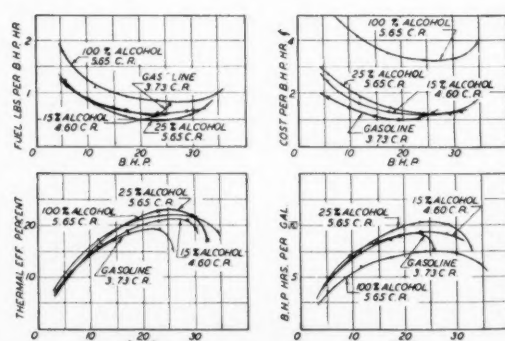
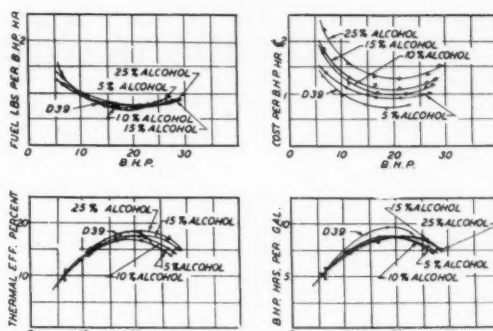
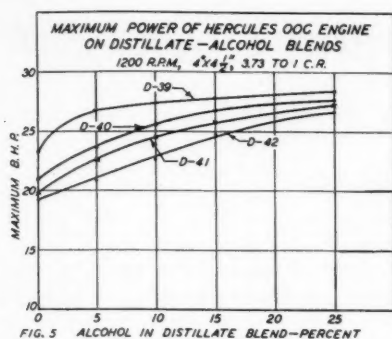


FIG. 4 BRAKE TESTS WITH HERCULES O.O.C. ENGINE 4 1/2 x 4 1/2, 1200 R.P.M., VARIOUS COMPRESSION RATIOS

¹Christensen, Leo M.; Hixon, R. M.; and Fulmer, Ellis I. The physical-chemical properties of alcohol-gasoline blends. Iowa State College Jour. Sci. Vol. VII, No. 4 (1933) pp. 461-466.



Results of tests on tractors No. 2 and No. 3 were similar in many respects to tractor No. 1 and are not shown.

The maximum power obtainable from tractor No. 2 on gasoline and 10 and 25 per cent blends was essentially the same. Detonation was not a limiting factor and performance was good on all fuels at all loads. The four factors used in the comparison, namely, thermal efficiency, specific fuel consumption, work per gallon, and fuel cost per horsepower-hour, were better with gasoline than with the alcohol blends.

With tractor No. 3 a slightly greater maximum power was obtained with gasoline. Thermal efficiencies were very nearly the same. Work per gallon, and pounds of fuel per horsepower-hour were consistently in favor of gasoline.

Hercules Engine Tests on Gasoline-Alcohol. A series of tests were run with a model OOC Hercules engine direct connected to a hydraulic dynamometer. This type of engine has been used considerably on combines and for other farm power purposes. It is a four-cylinder, 1200 rpm, 4-in bore, 4½-in stroke engine. Four different compression ratios were available as follows: 3.73 to 1, 4.6 to 1, 5.00 to 1, and 5.65 to 1. Fig. 4 gives the results of tests on 100 per cent alcohol, 100 per cent gasoline, and 15 and 25 per cent blends with the compression ratio most nearly optimum of those available. The carburetor jets had been drilled out oversize and needle valve adjustments adapted so it was possible to open the carburetor up enough to operate on alcohol. The 5.65 to 1 compression ratio was not high enough to get maximum performance from the alcohol. The 5.65 to 1 head gave satisfactory open throttle performance with the 25 per cent blend. The 15 per cent blend worked best with the 4.60 to 1 compression head. With gasoline and the 3.73 to 1 head, detonation was the limiting factor in determining maximum power. Five and ten per cent blends were run also, but they required the 3.73 to 1 head for open throttle loading, and these data have been eliminated from this report for simplification. Fig. 4 requires careful study to get clearly the results. One hundred per cent alcohol with the 5.65 to 1 head gave 34.3 hp for maximum power or 33.5 per cent greater than the 25.7 hp

produced with the 46.5 octane gasoline with the 3.73 to 1 head. The 15 and 25 per cent blends fall between these two extremes. The tendency of alcohol to show favorable thermal efficiencies, combined with the effect of higher compression ratios which may be used with it, are shown by the thermal efficiency curves. Thermal efficiencies obtained with the gasoline and 3.73 to 1 were definitely lower than the alcohol and alcohol-blend curves with their higher compression ratios. The blends were equal to or better than the straight gasoline in specific fuel consumption, while the 100 per cent alcohol ran a good bit higher. In terms of horsepower-hours per gallon, the blends were equal to or better than the gasoline, but 100 per cent alcohol fell short. In fuel cost per horsepower-hour, the gasoline was lowest, except at heavy-load operation where detonation was serious, the 15 and 25 per cent blends were equal to the gasoline. The 100 per cent alcohol fuel cost curve ranges about three times as high as the 100 per cent gasoline curve.

Engine Tests on Distillate-Alcohol Blends. A large number of tests were run with the Hercules engine described above on distillate-alcohol blends. Four distillates, D-39, D-40, D-41, and D-42, having octane values of 31.5, 14.1, 5.8, and 4.3, respectively, were used. Much of the data was of no significance and has been eliminated. Fig. 5 shows the effect of various admixtures of alcohol on the maximum power produced. All of these tests were run with a 3.73 to 1 compression ratio.

Fig. 6 gives the results of tests with distillate (D-39). This is an above-average-quality distillate having an octane number of 31.5. Maximum power was increased 23.3 per cent by the addition of 25 per cent alcohol. A maximum of 23.17 hp was obtained with distillate, while a 25 per cent blend gave 28.58 hp. The fuel consumption in pounds per horsepower-hour did not differ appreciably with the distillate and distillate blends. Undoubtedly the improved volatility, lower flash, and improved performance resulting from the alcohol blends tend to offset the lower heat content and normal tendency toward higher (Continued on page 78)

TABLE 4. FIELD TESTS WITH GASOLINE-ALCOHOL BLENDS
(Tractors No. 1 and No. 2 Pulling Two-bottom, 14-in Plow)

Test No.	Tractor No.	Farm	Fuel	Fuel cost per gal, cents	Speed, mph	Fuel, lb per acre	Fuel, gal per acre	Fuel cost per acre, cents
4	2	Agronomy	Gasoline	10.00	3.94	15.20	2.51	25.1
5	2	Agronomy	10% alcohol	11.50	3.96	16.70	2.74	31.5
6	2	Agronomy	25% alcohol	13.75	3.92	17.65	2.87	39.4
7	2	Travis	Gasoline	10.00	3.78	15.19	2.50	25.0
8	2	Travis	10% alcohol	11.50	3.76	16.50	2.70	31.1
9	2	Travis	25% alcohol	13.75	3.78	16.15	2.60	35.8
10	1	Peterson	Gasoline	10.00	2.08	15.37	2.52	25.2
11	1	Peterson	10% alcohol	11.50	2.02	16.53	2.71	31.2
12	1	Peterson	25% alcohol	13.75	2.04	17.70	2.85	39.2

Equipment, Methods, and Costs of Collecting Corn Stalks

By J. Brownlee Davidson

CHARTER A.S.A.E.

CORN STALKS are looked upon as one of the most promising of the various residues which may be used as a raw material for industrial uses. Although extensively grown, a large part of the crop is centralized in the corn belt. Of the 91,792,000 acres grown in the United States in 1938, 52 per cent were grown in the north central states, and 10,306,000 acres, or over 11 per cent, were grown in Iowa alone.

The yield of stalks varies much, but 1.5 tons per acre may be considered a normal yield. Harvesting methods practiced after the ears have been picked and a portion of the stalks down and wind-blown, give a yield of about one ton per acre. In the central part of the corn belt most of the corn is grown for the grain and little use is made of the stalks except for pasturage. The stalks, together with the grain left in the field, have a pasturage value of \$1.00 to \$1.50 per acre. It would seem that there is a large tonnage of corn stalks which can be made available when the return for the stalks can be made an inducement to the farmer. On the basis of an average of 200 acres per square mile, and an equal number of tons per square mile, a situation which prevails in the central corn belt, a total of a million tons would be available within a radius of 40 mi from a central factory location. Here we have the extraordinary situation of having a great volume of raw material produced regularly, awaiting utilization when a price can be paid that will interest the grower.

There is at least one factory which has been using corn stalks for some time in the manufacture of wall board. This company has paid, so it is reported, from \$8.00 to \$10.00 per ton for corn stalks at the factory. Since corn stalks in the field have a relatively low value, it would seem that the price suggested would be considerable inducement for farmers to market their crop. This factory has been in operation for ten or more years, but is poorly located in reference to the source of raw material. At the present time some of the stalks used are shipped more than 200 mi.

In the beginning, this factory made an effort to enlist the interest of farmers in harvesting and baling stalks for shipment. At present our best information indicates that most of the stalks are furnished by contractors who pay the grower a price for the stalks in the field. A division of the sale price of \$10.00 for a typical situation might be as shown in the accompanying table.

DISTRIBUTION OF THE COST PER TON OF BALED CORN STALKS AT THE FACTORY

Price received by farmer for stalks in the field	\$1.50	
Cost of breaking and raking	0.75	
Cost of baling	3.25	
Hauling and placing in car	1.50	
Freight	2.50	
Possible profit to contractor	0.50	\$10.00

An analysis of this kind should indicate the points of attack in an effort to reduce the cost of raw material and in-

Presented before the Power and Machinery Division at the fall meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 3, 1940, Journal Paper No. J- of the Iowa Agricultural Experiment Station, Project No. 476. Author: Professor and head of the agricultural engineering department, Iowa State College.

crease the return to the farmer, which in some instances may not be sufficient compensation for the fertility sold.

Baling is an expensive operation. It consumes much labor, power, wire, and equipment. It is more expensive to bale corn stalks than hay. The point might well be raised that if the stalks were chopped, baling might be dispensed with, when the material is delivered to a nearby factory.

Hauling and freight are variable items. The ideal situation would eliminate freight entirely.

There is much occasion for a criticism of the quality of raw material obtained by collection in the field after the grain has been harvested. The stalks contain much dust and even dirt from contact with the soil. It is suggested that for most purposes much of the softer portions of the corn stalks have little value for manufacture and should be left on the farm.

Present practices are a fair indication of what may be expected from the use of available equipment. If any great advance is to be made in the economy of harvesting corn stalks, new techniques and new equipment must be provided. Therefore, a research program should be instigated.

One of the first steps should be a careful engineering analysis, based on actual tests of the labor, power, and equipment expenditures required in carrying out the various operations with present equipment. Such an analysis should make for improved and more economical practices.

As a second stage, experiments should be made in handling the corn crop in new ways. The following experiments might well be conducted:

- 1 Collecting the stalks at the time of corn picking or field shelling.
- 2 Harvesting corn fodder and separation of grain and the more palatable portions of the stalks for feed from the coarser portions more useful for industrial purposes.
- 3 The practicality of handling corn in the chopped form, eliminating the expense of baling.

The program is essentially one that calls for cooperation. It has been suggested that the development of equipment for the harvesting of corn stalks could well be left to the manufacturers, and I think all would agree that the designs of the final machines are a responsibility of the manufacturer. On the other hand, experiments to determine principles and techniques might well be conducted at public expense.

There has been much discussion, extending back over a period of many years, relative to the possibilities of using corn stalks as a raw material for the manufacture of paper, strawboard, and similar products. It now appears that the use of corn stalks for such purposes will be hindered if not forestalled, if more efficient and more economical methods of harvesting and handling are not developed which will at the same time give the corn grower more for his crop and supply the factory a lower cost raw material than is now available. The problem is very definitely an engineering problem and agricultural engineers should accept the challenge of finding its solution.

Automatic Feed Control for Small Feed Grinders

By C. J. Hurd

MEMBER A.S.A.E.

THE Tennessee Valley Authority began work in 1935 on the development of automatic feed control devices for small feed grinders. A report on the preliminary studies was given in a paper, entitled "Small Feed Mill Design and Performance," by Geo. W. Kable and A. T. Hendrix, presented at the fall meeting of the American Society of Agricultural Engineers in 1935, and in an article of the same title by A. T. Hendrix, in AGRICULTURAL ENGINEERING for October 1937.

Subsequent work by the Authority on automatic feed control devices resulted in the development of a mechanically vibrated feed table with solenoid operated dampening device controlled by the current flow in the electric motor. The principle of this control device is covered by U. S. Patent 2,129,688, issued September 13, 1938, to A. T. Hendrix, and assigned to the Tennessee Valley Authority.

Since 1938 additional laboratory and field studies have been made, leading to further refinements of the control and vibrated feed table. This work, conducted by W. C. Gillham, assistant agricultural engineer of the Authority, resulted in the development of an electromagnetic vibrator feed table with solenoid control, as shown in the schematic drawing, Fig. 1.

Principle of Operation. The feeding mechanism consists of a table or trough carried upon a resilient support and vibrated by means of an electromagnet.

The controlling mechanism consists of a solenoid connected in series with the motor driving the feed mill. The solenoid is energized by the current that operates the motor in direct ratio to the amount of current supplied to the motor. The pull exerted by the coil is partially balanced by a spring, which, in practice, is made adjustable so that the same unit can be adapted to different sizes of motors. In operation this spring is so adjusted that when the motor becomes loaded above its rated horsepower, the coil pulls the solenoid plunger against the spring resistance, and in so doing actuates a mechanism which breaks the circuit to the electromagnet that vibrates the feed table. As long as this circuit is broken no grain is fed to the grinder, so the load on the motor drops off. When this load drops to a predetermined point, which is about 85 per cent load, the coil loses enough of its pull to allow the spring to return

the plunger to its original position. In returning to its original position, the plunger again actuates the mechanism, which restores the circuit through the vibrator coil. In this way the grain is fed or shut off, as needed, keeping the motor load at near 100 per cent load. A manually operated gate in the feed table allows the operator to set the feeder according to the amount of grain required by the grinder. As this adjustment is not critical, it can readily be set so that the circuit is only occasionally interrupted.

Field Studies. Ten controllers, as described above, were built in 1939 and put on field trial in cooperation with the agricultural extension services of Alabama, Mississippi, Tennessee, and Georgia. Conventional hammer mills were used, operated by $\frac{1}{2}$ to 1-hp motors. Results of the operation of these mills by farmers were uniformly satisfactory, with only one reporting that the electric motor current apparently did not increase sufficiently between light and heavy loads to cause the controller to work correctly. When another motor was installed the controller worked satisfactorily. Since both capacitor and repulsion-induction motors in the $\frac{1}{2}$ and 1-hp sizes have a $\frac{3}{4}$ to 2-amp current increase between 75 per cent and 125 per cent loads, and since the solenoid control operates on a total differential of $\frac{1}{4}$ amp, it was assumed that this particular motor had some mechanical or electrical fault.

The $\frac{1}{2}$ and 1-hp mills equipped with the controller had sufficient capacity to grind all of the small grains for farms having 500 to 1000 chickens to farms feeding 20 steers and 12 hogs. Ben P. Hazlewood, superintendent, West Tennessee Agricultural Experiment Station, who used this controller on a $\frac{1}{2}$ -hp motor-driven hammer mill for over a year, reports it has sufficient capacity to grind shelled corn or small grains for 100 to 150 steers, since the mill can be left unattended and be operated over long hours.

Use of Controller for Larger Mills. Tests have not been made using this type of automatic feed control for mills using motors in excess of 1 hp. Although there may be no mechanical difficulty in controlling the rate of feed of grain when using a 3 to 5-hp grinder, there is the practical problem of having a feed control applicable for larger mills when grinding roughage, ear corn, etc. The rate of feed of these materials probably could not be regulated with a vibrating feed table; therefore, it is believed that this controller is best suited for mills of 1 hp or less, or when the grinder is to be used exclusively for grinding shelled corn or small grain.

Paper presented before the Rural Electric Division at the fall meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 5, 1940. Author: Chief, agricultural engineering development division, commerce department, Tennessee Valley Authority.

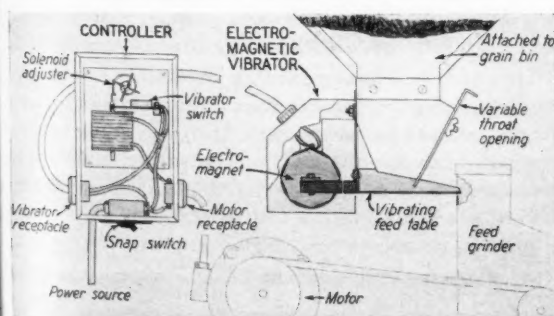


Fig. 1 Schematic view of automatic feed control for small feed grinders designed for use with $\frac{1}{2}$ and 1-hp electric motors

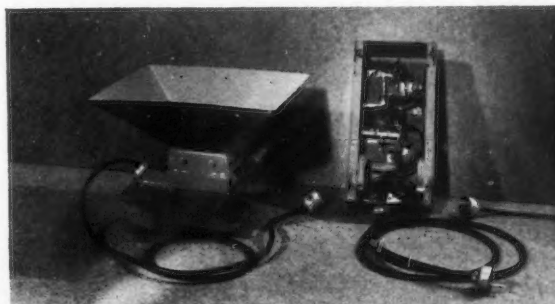


Fig. 2 Electro-vibrator feed (left) for attachment to overhead grain bin, and solenoid control (right) showing cover removed and attachment cords for motor and power supply

POWER

SPEED

FLEXIBILITY

HIGH COMPRESSION

This is the McCormick-Deering Tractor that holds the official Nebraska Tractor Record for fuel economy.



MCCORMICK-DEERING TRACTOR USING REGULAR GASOLINE SETS NEW FUEL ECONOMY RECORD IN NEBRASKA TRACTOR TESTS

IN THE official Nebraska Tractor Tests a high compression McCormick-Deering W-6 tractor using regular gasoline delivered 12.49 horsepower hours per gallon—a new record for fuel economy.

This new fuel economy record shows the rapid strides that are being made in the development of the high compression farm tractor. It is tangible proof of the practical value of cooperative research by the nation's tractor manu-

facturers and petroleum technologists.

The International Harvester Company is to be congratulated for establishing another milestone in more efficient power farming—more efficient power, that will save American farmers millions of gallons of fuel and oil.

This progress has opened up new sales opportunities for the tractor dealer. Tremendous improvements in farm tractor power, speed, convenience, flexibility and economy have resulted from the use of good gasoline, plus high compression. These advances offer the tractor operator a reward for replacing his old machine. It pays him to—and you to sell—a new high compression tractor.

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ECONOMY

COPY OF REPORT OF OFFICIAL TRACTOR

TEST NO. 355

UNIVERSITY OF NEBRASKA—AGRICULTURAL ENGINEERING DEPARTMENT—AGRICULTURAL COLLEGE, LINCOLN

Copy of Report of Official Tractor Test No. 355

Dates of test: September 16 to 27, 1940. Name and model of tractor: McCORMICK-DEERING W-6 (Gasoline). Manufacturer: International Harvester Company, Chicago

Illinois. Manufacturer's rating: NOT RATED.

BELT HORSEPOWER TESTS

BELT HORSEPOWER TESTS								
H.P.	Crank shaft speed R.P.M.	Fuel Consumption			Water used gal. per hr.	Temp. Deg. F.		Barometer Inches of Mercury
		Gal. per hr.	H.P. hr. per gal.	Lb. per H.P. hr.		Cooling med.	Air	
TEST B—100% MAXIMUM LOAD—TWO HOURS								
36.97	1450	2.964	12.47	0.496	0.000	193	78	29.050
TEST C—OPERATING MAXIMUM LOAD—ONE HOUR								
36.15	1449	2.895	12.49	0.496	0.000	192	82	29.070
TEST D—ONE HOUR								
33.11	1449	2.750	12.04	0.514	0.000	199	91	29.095
TEST E—VARIABLE LOAD—TWO HOURS (20-minute runs; last line average)								
32.89	1447	2.743	11.99	0.516	.....	200	91	.....
1.36	1561	1.265	1.08	5.757	.....	201	90	.....
17.28	1507	1.977	8.74	0.708	.....	197	92	.....
33.33	1393	2.806	11.88	0.521	.....	199	94	.....
8.83	1542	1.614	5.47	1.131	.....	200	94	.....
25.54	1479	2.375	10.75	0.576	.....	198	96	.....
19.87	1488	2.130	9.33	0.664	0.000	199	93	29.105

DRAWBAR HORSEPOWER TESTS

DRAWBAR HORSEPOWER TESTS											
H.P.	Draw bar pull pounds	Speed miles per hr.	Crank shaft speed R.P.M.	Slip on drive wheels %	Fuel Consumption			Water used gal. per hr.	Temp. Deg. F.		Barometer Inches of Mercury
					Gal. per hr.	H.P. per gal.	Lb. per H.P. hr.		Cooling med.	Air	
TEST F—100% MAXIMUM LOAD—Second—GEAR											
32.48	4282	2.84	1451	10.84	Not Recorded				191	67	28.930
TEST G—OPERATING MAXIMUM LOAD											
25.13	4777	1.97	1452	17.23	Not Recorded				197	62	29.000
31.44	4173	2.83	1451	11.44	Not Recorded				192	63	28.990
32.33	3156	3.84	1450	7.66	Not Recorded				193	66	28.955
32.14	2545	4.74	1451	6.12	Not Recorded				191	65	28.920
*TEST H—TEN HOURS—Second—GEAR											
25.48	3238	2.95	1450	6.84	2.525	10.09	0.613	0.000	199	63	29.110

*Formerly called RATED LOAD; see REMARKS 4, page 3.

*Formerly called RATED LOAD; see REMARKS 4, page 3.

FUEL, OIL AND TIME: Fuel—Gasoline, Octane—73, Weight per gallon—6.19 pounds. Oil—S.A.E. No. 20, To motor—2.486 gal., Drained from motor—2.153 gal. Total time motor was operated—45 hours.

BRIEF SPECIFICATIONS: Advertised speeds miles per hour: First—2 $\frac{3}{4}$, Second—3 $\frac{1}{2}$, Third—4, Fourth—4 $\frac{1}{2}$, Fifth—14 $\frac{1}{2}$, Reverse—2 $\frac{1}{4}$. Belt pulley: Diam.—11", Face—7 $\frac{1}{2}$ ", R.P.M.—898, Belt Speed—2587 f.p.m. Clutch: Make—Rockford, Type—Single plate, Operated by foot. Seat: Pressed steel with sponge rubber pad. Total weight as tested (with operator): 7610 pounds.MOTOR: Make—Own, Serial No. WBK 511XI, Type—4 cylinder vertical, Head—I, Mounting—Crankshaft lengthwise, Lubrication—Pressure, Bore and stroke—3 $\frac{1}{4}$ " x 5 $\frac{1}{4}$ ", Rated R.P.M.—1450. Port diameter valves: Inlet—1.594", Exhaust—1.438". Magneto: Make—Own, Model—H-4. Carburetor: Make—Own, Model—E-12, Size—1 $\frac{1}{4}$ ". Governor: Make—Own, Type—Variable speed, centrifugal. Air Cleaner: Make—Donaldson, Type—Oil-washed, wire screen filter. Oil filter: Make—Motor Improvement, Inc., Type—Partial flow with replaceable bakelite impregnated paper element. Cooling medium temperature control: Bishop and Babcock thermostat and Fines radiator shutters.CHASSIS: Type—Standard, Serial No. WBK 511XI, Drive—Enclosed gear. Tread width: Rear—53", Front—46 $\frac{3}{4}$ ". Rear tires: No. 2, size—13.50 x 24, 6 ply, Air Pressure—16 pounds. Front tires: No. 2, Size 6.50 x 16, 4 ply, Air pressure—25 pounds. Added weight: Per rear wheel: Cast iron—970 pounds, Water—336 pounds, Per front wheel: Cast iron—80 pounds, Water—None.

REPAIRS AND ADJUSTMENTS: No repairs or adjustments.

REMARKS: 1. All results shown on page 1 of this report were determined from observed data and without allowances, additions or deductions. Tests B and F were made with carburetor set for 100% maximum belt horsepower and data from these tests were used in determining the horsepower to be developed in tests D and H, respectively. 2. Observed maximum horsepower (tests F & B): Drawbar, 32.48; Belt, 36.97. 3. Sea level (calculated) maximum horsepower (based on 60°F. and 29.92" Hg.): Drawbar, 33.81; Belt, 38.74. 4. Seventy-five per cent of calculated maximum drawbar horsepower and eighty-five per cent of calculated maximum belt horsepower (formerly A.S.A.E. and S.A.E. ratings): Drawbar, 25.36; Belt, 32.93.

I, the undersigned, certify that the above is a true and correct report of official tractor test No. 355.

CARLTON L. ZINK, Engineer-in-charge.

E. E. BRACKETT, C. W. SMITH, L. W. HURLBUT, Board of Tractor Test Engineers.

SS OF TRACTOR

NEWS

Arnold Yerkes Promoted

ARNOLD P. YERKES, a past-president of the American Society of Agricultural Engineers, and editor of "Tractor Farming", a publication of the International Harvester Company for its farm equipment users, has recently been promoted and placed in full charge of the Company's new division of farm practice research.

This new division will centralize the company's research activities in connection with new developments in farming practices and effective use of equipment, new uses for farm products, and new requirements to be met by new or modified equipment. It will also keep in touch with related research in the U. S. Department of Agriculture and in the state colleges and experimental stations.

Mr. Yerkes served as chairman of the Power and Machinery Division of the A.S.A.E. in 1925-26, and as president of the Society in 1937-38. For the past several years he has also represented the agricultural engineering field on the board of governors of the National Farm Chemurgic Council. Prior to joining the Harvester Company in 1918, Mr. Yerkes served six years in the office of Farm Management, U. S. Department of Agriculture—three years in charge of tractor investigations in the Division of Farm Equipment and the other three years in charge of the Division.

Personals

Clint W. Bracher was recently appointed a "junior agricultural engineer" with the U. S. Soil Conservation Service and is located at Yoakum, Texas. He is a 1940 agricultural engineering graduate of the A. & M. College of Texas.

Henry L. Espensen is now employed as agricultural engineer of Rilco Laminated Products, Inc., Albert Lea, Minnesota, a subsidiary of Weyerhaeuser. He is a 1940 agricultural engineering graduate of Iowa State College.

F. L. Fairbanks and A. M. Goodman have recently revised Cornell Extension Bulletin 151 on "Dairy-Stable Ventilation," which was originally published in 1926.

W. H. Farmer recently received an appointment as associate civil engineer with the Farm Security Administration, specializing in irrigation. His new address is 1025 14th Street, Denver, Colorado. He was previously assistant extension agricultural engineer in the North Dakota Agricultural College.

Leo Larsen, a 1940 graduate in agricultural engineering from South Dakota State College, is employed in the experimental department of the John Deere Harvester Works. His address is 1017 13th St., East Moline, Ill.

Ellen Pennell was recently appointed home economics director of National Biscuit Company, with headquarters at 449 West 14th



A group of senior agricultural engineering students of the A & M College of Texas during their annual inspection trip (See news item of Texas Student Branch of A.S.A.E. in AGRICULTURAL ENGINEERING for December 1940, page 494)

A.S.A.E. Meetings Calendar

June 23-26, 1941—Annual Meeting, Knoxville, Tenn.

.....—North Atlantic Section, Jackson's Mills, W. Va.

December 1-3—Fall Meeting, Stevens Hotel, Chicago.

St., New York. Until recently she held a similar position with the Associated Grocer Manufacturers of America, and previous to that was editor of the homemaking department of "The Country Home Magazine."

James B. Robinson, Jr., was recently appointed junior agricultural engineer of the U. S. Soil Conservation Service, and is located at Colorado City, Texas. Until his appointment he was in the employment of the Goodyear Tire and Rubber Company.

S. A. Witzel is one of the authors of Wisconsin Agricultural Extension Circular 309 on "Sewage Treatment and Disposal for Farm Homes."

Student Branch News

Saskatchewan

By J. Paterson

AN organization meeting for the year 1940-41 was delayed until after the middle of October as several of the boys were not able to come in when University opened the last week in September.

The membership this year is larger than ever, and, though all activities are necessarily curtailed because of the war, yet almost thirty students are members of the Branch. Of these, about twelve are local members and the remainder are student A.S.A.E. members.

In all, a total of six meetings were held the first term, or an average of one each week. Meetings were discontinued about the first of December because of Christmas examinations. The meetings are, for the most part, held in the afternoon at 4:30, with an evening meeting about once a month.

A public speaking group was organized early in the term, and two of the meetings each month are devoted to short talks by the members, on agricultural engineering subjects. One meeting was spent with an interesting report by the boys who attended the A.S.A.E. annual meeting and the Industry Seminar.

This year, the Branch is out to win the F.E.I. Cup and the committee is now busy working on the report. It is the first time they have entered the competition since the Branch was re-organized in 1938. It was won by the group several years ago.

The new addition to the engineering building, completed last term, provides more spacious quarters for the agricultural engineering department. (News continued on page 74)



The Saskatchewan Student Branch and faculty pose in one of their department laboratories

"CATERPILLAR" MOTOR GRADERS MOTORIZE TERRACE-BUILDING!

- ➡ "Caterpillar" Diesel Motor Graders are literally rolling from highways to fields—bringing to terrace-building advantages that are now revolutionizing road-building and maintenance practices the world over!
 - ➡ Tandem drive wheels, without rear-axle differentials—carrying a rear-mounted engine's weight—furnish the kind of pull-bracing traction that only a well-balanced track-type tractor could formerly give!
 - ➡ Time-saving power controls give the *one* operator command of the full range of useful blade positions *quickly*—without dismounting from the deep-cushioned seat. And this machine has the mobility to propel itself at 10 to 15 miles per hour from farm to farm, on any kind of roads—*3 times as fast as is practical for a tractor and terracer to travel.*
 - ➡ A No. 212 Diesel Motor Grader (like the one shown here) averaged building over 700 feet of completed Nichols-type terrace per hour in 5 Georgia counties. Emanuel County (Georgia) Farmers Marketing Association, Inc., built 22,000 feet of terraces in the first 3½ days, with a "green" operator on their No. 212!
- All 3 sizes of "Caterpillar" Diesel Motor Graders promise to *motorize*—bring new speed and economy to terracing—under many conditions. For more information, write us!
- CATERPILLAR TRACTOR CO., PEORIA, ILLINOIS**

CATERPILLAR *Diesel*

REG. U. S. PAT. OFF.

DIESEL ENGINES

TRACK-TYPE TRACTORS

TERRACERS



Student Branch News

(Continued from page 72)

GEORGIA

By Billy Strauss

GEORGIA'S Student Branch of the A.S.A.E. held its last meeting of the fall quarter on December 23, 1940. This meeting was given over entirely to the election of the new officers for the winter quarter, who are as follows: President, J. E. Payne; vice-president, G. H. Kimbrell; secretary, W. D. Kenney; and scribe, W. A. Strauss.

The first meeting of the winter quarter was held on January 13, 1941. During this meeting a committee was appointed for gathering the necessary material to compete in the F.E.I. Cup Award. The program committee announced programs for the remainder of the quarter, as follows: January 27, Employment possibilities in the fields of agricultural engineering (entirely student program); February 10, Reports of students and faculty members attending the Southern Section A.S.A.E. meeting in Atlanta; February 24, A question and answer program put on by the program committee (students participating); March 10, A talk by Dean Weddell of Forestry School, and election of officers for spring.

The membership committee reported that 70 students were enrolled in the agricultural engineering department, 17 being seniors, 21 juniors, 14 sophomores and 18 freshmen.

It was decided upon by faculty and students that the students should have more active parts in the meeting instead of having the meetings feature men outside of the department. This meeting was closed after a motion picture, sponsored by the Byers Iron Industry of Philadelphia, was shown.

At the second meeting for the month of January, plans got under way pertaining to the part the agricultural engineering department has in the 4-H Club Carnival to be held at the University on February 28.

It was reported that the Branch is going to have a radio program during the latter part of the month of February. A committee for this purpose was appointed by the president.

The program committee announced that student-faculty forums are going to prevail at the end of each meeting, so the students may discuss their problems freely with the members of the faculty.

The Annual Convention of the Association of Southern Agricultural Workers is to be held in Atlanta early in February and many students and faculty members are going to be present from this department. The A.S.A.E. Southern Section meeting is held in conjunction with it.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the January issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Forest C. Braden, territory manager, John Deere Plow Company, San Francisco, Calif. (Mail) 30 Medlock Drive, Phoenix, Ariz.

C. G. E. Downing, agricultural engineer, Dominion Experiment Station, Swift Current, Sask., Canada.

George Theon Finlison, district engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Sayre, Okla.

Edw. G. Gallagher, sales engineer, Kankakee Tile & Brick Company, Kankakee, Ill.

Charles Mablou Hummel, Junior Agricultural Engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 134, Wentzville, Mo.

William A. Hyland, chief engineer, experimental department, VanBrunt Mfg. Co., Horicon, Wis.

George H. Priest, Jr., director, technical field service, National Paint, Varnish & Lacquer Association, 1500 Rhode Island Ave., N. W., Washington, D. C.

Adolph Ronning, pres.-treas., Ronning Machinery Company, 5030 Woodlawn Blvd., Minneapolis, Minn.

Austin W. Zingg, assistant agricultural engineer, Soil Conservation Service, U. S. D. A. (Mail) Bethany, Mo.

TRANSFER OF GRADE

Harry Paul Bateman, assistant in agricultural engineering, University of Illinois, Urbana, Ill. (Junior to Member)

James Dewey Long, agricultural engineer, Douglas Fir Plywood Assn., Tacoma, Wash. (Mail) 215 S. 8th St., Fredonia, Kans. (Member to Fellow)

Billion-Dollar Cushion

(Editorials continued from page 44)

this surplus in preparation to minimize our impending post-war emergency.

One suggestion has come to us from within the agricultural engineering field and relating to it. A program of rehabilitating farm buildings could be developed as a billion-dollar-a-year cushion during the period of readjustment of business to peacetime production. Briefly, here are the considerations, as represented to us.

Farm houses and other buildings are known to fall far short of desirable standards to meet living and production needs. New construction, remodeling, and routine maintenance have been postponed during the past two decades of quite general agricultural depression.

Specifically, it is estimated that 250,000 new farm houses per year, 700,000 other new farm buildings, and repairs and improvements to a still larger number of existing buildings will be needed each year for the next ten years to overcome the present shortage and provide for normal replacement.

One billion dollars per year is a low estimate for the investment value of this amount of building, even with allowance for reduction of cash outlay through use of local materials and home labor.

It is also well within farm ability to finance, without subsidy. It means an average of about \$150 per year for each farm in the United States, or of about \$250 per year for each of the 60 per cent of our farms which are free of mortgage indebtedness. This is considerably less per capita than urban investment in housing and construction for business operations. It represents about three times the present level of farm building operations.

This amount of farm building activity can be brought about by furnishing competent, free architectural and engineering advice to farmers who want to make building improvements, and need only help to get started. It is known that farmers generally have a latent or potential desire to improve their buildings, which becomes effective when they are shown what it can do for them, that it is within their means, and how to get most value for the money they might invest. The program contemplated would provide schools and demonstrations, as well as individual service, to clarify these points for farmers.

It would have the sound farming, business, and engineering objective of encouraging this use of available manpower, money, and materials only whenever and however their use in improving farm buildings could be clearly justified by the estimated contribution of such improvements to the material and living values to be realized by the farm family.

Through the machinery of the cooperative agricultural extension service of the U. S. Department of Agriculture and the state colleges, this service to farmers could be provided by the employment of several extension specialists in each state, at a total cost of about one dollar per farm. The extension setup already provides the nucleus of the organization needed to do the job, but would need several times as many men as it now has in farm buildings work.

To be ready to start the job promptly when defense industry slows up and the cushion is needed, men need to be trained, some research done, and details worked out in advance. The time to start that advance preparation is now.

Building material interests have a logical place in the planning and execution of the program, to see that their materials are used in ways

(Continued on page 76)

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page 76)



WHAT IS THIS CONTEST?

The National 4-H Club Rural Electrification Contest offers recognition and reward to club members for their study of the uses of electricity on the farm and in the home in connection with their regular 4-H Club projects. It supplements their regular State 4-H Club program. Thus, of first importance it is necessary that members fulfill the requirements of regular projects.

In States accepting this contest, any 4-H Club member may enter with the approval of the County Extension Agent.

There is a wide difference among States as well as

among 4-H Club projects. This contest allows ample opportunity for the use of initiative by the club member, the club leader, and the club as a unit.

It is not necessary, in order to enroll in this contest, that the club member have electricity or even have a large number of electrical appliances or equipment. Thus, the contest is open to those with or without the benefit of electric service.

The County Extension Agent (Agricultural, 4-H Club, or Home Demonstration) can tell any applicant if the program has been accepted for his or her State.

WHAT DOES IT MEAN TO CLUB MEMBERS?

Approximately two million farms now enjoy the benefits of electricity. This means changes in many phases of farming and farm living. These changes extend into all kinds of 4-H Club work.

Thus there is a need on the part of the club member to under-

stand the many problems of electricity itself as well as to know better ways and means of putting it to work.

Like all kinds of 4-H Club work, this contest offers both recognition and rewards for work well done.

HOW CAN THE CLUB MEMBER TAKE PART?

After enrollment in one or several regular 4-H Club projects conducted under the direction of the Extension Service, the club member is eligible for enrollment in this contest. Enrollment should be made with the County Extension Agent. Some States have provided rural electrification programs of their own, and this contest is often made a part of it.

The rules are simple and the opportunity for using initiative is great. Everyday experience throughout the year can be used to advantage in making up the member's final report.

Electricity, the newest addition to agriculture, is the newest subject for club work and will be found of interest and help to the club member and his club.

FOR LOCAL LEADERS ▶

Use the coupon at the right to bring to you much helpful information. If you will supplement the coupon with a letter giving some specific needs of your club,

additional bulletins not available for wide distribution will be included. We will need to know the interest of your club members to be of the greatest service to you.

Westinghouse



ELECTRICAL PARTNER OF AGRICULTURE

SEND THIS COUPON TODAY
Westinghouse Rural Electrification
306 Fourth Ave., Pittsburgh, Pa.

Please send me copies of Rural Elec. literature
including new 1941 Contest Guide Book.

☐ I am a 4-H Club Leader with...Boys and
(Please check (✓) which one)...Girls interested

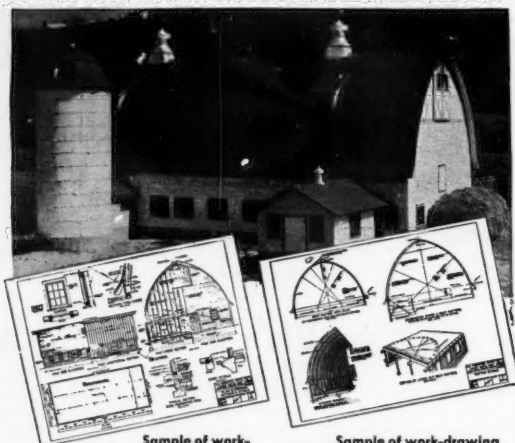
Print Name.....

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County.....State.....

IRI-4

How Johns-Manville has brought Fire Protection, Lower Upkeep, Sanitation and Long Life to Farm Buildings ... AT LOW COST



Sample of work-drawing for erecting Asbestos Gothic-type barn, shown above.

Sample of work-drawing giving directions for sawing and bending rafters.

TODAY, AS ALWAYS, three major enemies of a farmer's profits are FIRE, Weather and Wear. These enemies attack badly designed and neglected farm buildings, increase operating costs, lessen the productivity of stock and, in the case of FIRE, wipe out years of profitable operation in a single night!

J-M Engineers brought their outstanding Research and Development facilities to bear on this triple problem . . . Adapted asbestos materials and Rock Wool insulation to correctly designed farm structures . . . Brought down first costs . . . Lowered upkeep costs . . . Added FIRE PROTECTION, sanitation and lasting appearance . . .

Johns-Manville will continue to co-operate with leading agricultural authorities to bring to the farmer more and more value for his building dollar. J-M Engineers are always willing to discuss your individual, or sectional, building or remodeling problem.

Whynot send for the complete J-M Farm Information Service (with construction details) illustrated below. You should have these bulletins in your reference library . . . Coupon brings them FREE.

SEND NOW FOR THESE FOLDERS



JOHNS-MANVILLE, Dept. AE-M-2, 22 E. 40th st., N.Y.C.
Gentlemen: To assist in my work, I would like to have your complete Farm Information Service.

Name _____ Position _____

Name of College _____ Address _____

Town _____ State _____

Billion-Dollar Cushion

(Editorials continued from page 74)

that will insure greatest satisfaction. And neither they nor organized labor need to fear the use of farm materials and labor in such construction. Experience has shown that the practice does not decrease the total amount of money spent for materials, the labor represented in them, and other skilled labor; but that it can give the farmer more value for his money, making him a better satisfied customer and a better prospect for further building.

This is only one possible way of cushioning the future shock of a sharp decrease in defense industry. Alongside of our total government debt, national income, or the whole volume of the building industry, this billion-dollar-a-year business may seem a small factor. But from almost any other standpoint, a billion dollars is still big business. It looks particularly big as mostly new business; as an extra that could mean the difference between satisfactory volume and depression volume of business in the building industry. It looks big as a cushion for men to be dropped some time from defense employment. It looks big as money in circulation, contributing to the margin between profit and loss, employment and unemployment, in our whole national economy. We think it is biggest of all as an idea—a suggestion and concrete example of how things can be done to develop, support, and encourage a free private enterprise economy in the production, exchange, and consumption of peacetime goods and services with the effectiveness and in the volume that can be called prosperity.

Grass Silage Quality

FOOD for thought about food for cattle is provided in the paper, entitled "Observations on the Storage of Grass Silage," published elsewhere in this issue. It is noted that some excellent silage is reported to have been produced in spite of severe leakage, and some poor silage where there was little or no leakage. However undesirable leakage might be from other standpoints, this suggests that it is not a controlling factor in silage quality.

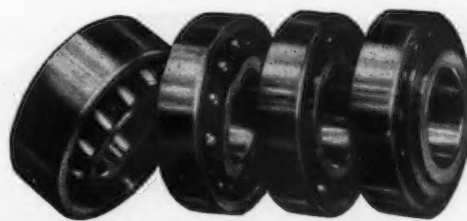
While the number of cases reported is too small to be conclusive, two instances of extensive top spoilage and one of uniformly poor silage are recorded where timothy was included in the material ensiled, and timothy was not included in any case where the silage is definitely noted as good or excellent. Special consideration of methods may be indicated where timothy is to be ensiled. Clover, alfalfa, mixed grasses, oats, and peas produced good silage with a variety of treatments.

Some good silage is reported where only 40 pounds of molasses per ton were used, and some severe top spoilage where the preservative was 100 pounds of molasses per ton. No case of serious spoilage or poor silage is recorded here against phosphoric acid as a preservative.

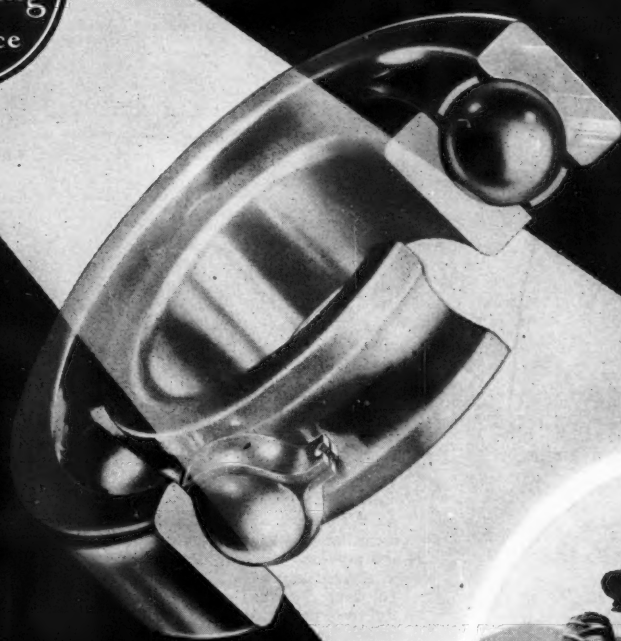
Checking quality and spoilage recorded against moisture content of the ensiled material shows that, in these experiments, good quality is reported only where the moisture content was average to high; whereas poor quality or considerable top and side spoilage is reported only for moisture rating average to low. Top spoilage reported occurred in spite of coverings of mulch paper and at least a ton of chopped grass. This suggests giving special attention to the packing and topping of low-moisture silage.

A lot remains to be learned about grass silage. Enough has been learned to show that the silo itself, and the mechanics of harvesting and ensiling the grass, are prime influences on cost and quality.

IT'S EASIER



TO SELL AN SKF-EQUIPPED TRACTOR THAN TO SELL AGAINST IT



BUILT BY OLIVER FARM EQUIPMENT CO.

BECAUSE they use SKF Bearings, it's easy to paraphrase Oliver's slogan: "It's better to be selling an Oliver Tractor than to sell against it."

The well-known letters "SKF" on the bearings of Oliver tractors is a warranty to you as a dealer and to your customers as users, that the *right* bearings are in the right places.

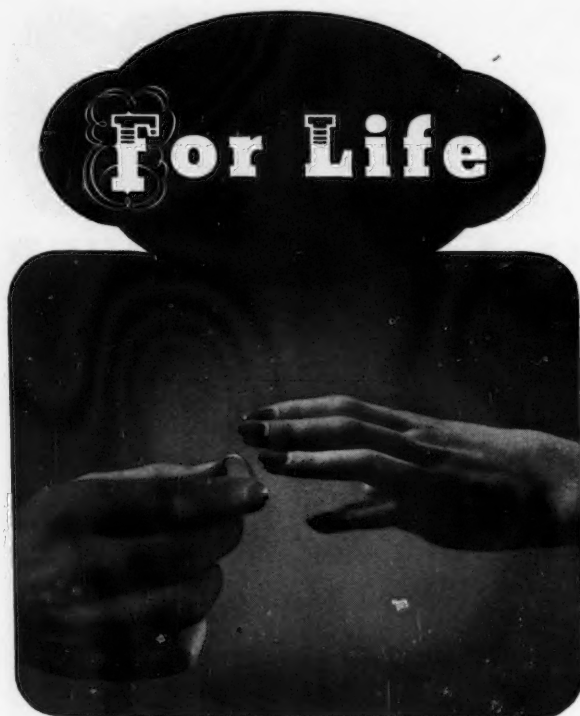
They're assurance of freedom from bearing trouble on main drive, bevel pinion, clutch, P.T.O. and transmission shafts... of economical tractor operation, dependable performance and easy handling. Stress "SKF" for profits.

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BALL & ROLLER BEARINGS



Makers of tractors,
combines, hammer mills and other
fast-moving farm equipment
have a life-time interest in the
machinery they make and sell.
That is one reason why so many
of them have turned in recent years
to BCA Ball Bearings to carry
the load and reduce friction
under the severe conditions demanded
of modern farm machinery.
With the defense program
creating new labor shortages
on American farms, good farm
machinery, equipped with
BCA Ball Bearings, will be
more important than ever.

BEARINGS COMPANY OF AMERICA
421 Harrisburg Ave., Lancaster, Pa.



BCA RADIAL-ANGULAR CONTACT-THRUST
Ball Bearings

Power Alcohol in Tractors and Farm Engines

(Continued from page 67)

fuel consumption. The thermal efficiency of the 15 and 25 per cent blends is about the same as distillate up to the load at which detonation became a factor with distillate, but at loads above that they show higher efficiencies. The brake horsepower-hours per gallon were consistently higher on 100 per cent distillate. The 15 and 25 per cent blends show up better than the 5 and 10 per cent blends at heavy loads due to their higher antiknock values. The fuel costs were lowest with distillate and became progressively higher as the alcohol content was increased. In view of the relatively high antiknock values of the 15 and 25 per cent alcohol-distillate blends, they were run with a 4.6 to 1 head (data not included), but detonation was severe and in no case was the maximum power increased above the maximum developed with the 3.73 to 1 head.

AUTHOR'S ACKNOWLEDGMENT: Credit is given Robert J. McCall and Arthur H. Thompson, former students, now assistants in the departments of agricultural engineering at Ohio State University and University of Minnesota, respectively, for the large part of the work they did in running tests and computing results.

Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, assistant chief, Office of Experiment Stations, U. S. Department of Agriculture. Copies of publications reviewed may be procured only from the publishers at the addresses indicated.

RANGE IMPROVEMENT THROUGH CONSERVATION OF FLOOD WATERS.—A REPORT OF PROGRESS, O. W. Monson and J. R. Quisenberry. (Coop. U.S.D.A.). Montana Sta. (Bozeman) Bul. 380 (1940), pp. 20, figs. 16. This bulletin reports measurement of the actual runoff from small watersheds, determination of the extent to which this runoff can be recovered and used, and an investigation of the possibilities of range revegetation of the conservation and use of such runoff water.

As a means for runoff measurement, a 4-ft Parshall flume was placed at the mouth of a coulee receiving the runoff from about 2 sq mi of watershed. This flume was equipped with an automatic water-stage recorder so controlled by a float as to operate only during actual water flow.

Water passing through the coulee was prevented from following a large gully to the river by an earth dam, or dike, 3 ft high and provided with five 20-ft spillways for distribution of the water. In three areas three methods of utilizing this water were tested. The first, described as free flooding, but including the use of two shallow contour ditches to prevent localization of the water in swales and low spots, appeared to be adapted to lands having slopes up to 5 per cent. The second control procedure, described as "controlled flooding," and involving a system of dikes at right angles to the slope and almost on the contour, was designed to direct the water back and forth across the slope. Dikes 16 in high, graded 0.05 per cent, and about 1,200 ft in length were used. Natural vegetation of both dikes and borrow pits is progressing well. Of these experiments it is stated that the method of meandering flooding is adapted to slopes of less than 1.5 per cent. For steeper slopes the contour spreading ditches should be used. On a third area, having a slope of less than 1 per cent, a procedure described as ponding or check flooding was tested. Dikes from 12 to 14 in high backed up the water over strips 100 ft wide. Contour dikes at contour intervals of 0.8 ft were provided with ripped spillways about 100 ft apart to prevent overtopping. Dikes and spillways were successfully seeded to bromegrass. Crested wheatgrass also gave good results and responded well to flood irrigation, though its growth was less heavy than that of the bromegrass. This method gave better penetration of the water than did the mere flooding over of the surface, but it concentrated the available water on a smaller area of land.

IMPROVISED FERTILIZER DISTRIBUTOR, R. H. Means. Miss. Farm Res. [Mississippi Sta. (State College)], 3 (1940), No. 9, p. 7, fig. 1. The design of this machine was adapted from that of a smaller distributor of the wheelbarrow form. Old cultivator wheels (not specified) of the fertilizer box, or width of the machine, and provided with agitators. The rate of distribution was controlled by a strapiron strip, 2x1/4 in, carrying holes ranging from 3/8 to 1/2 in in diameter. The machine was found adjustable to a minimum rate of distribution of 150 lb of superphosphate per acre and up to a maximum of 400 lb per acre. Capacity of the fertilizer box was about 400 lb superphosphate. Cost of construction about \$5.

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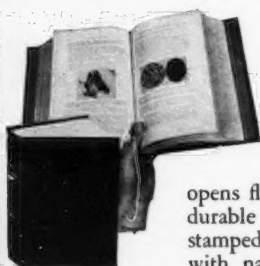
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EMPLOYMENT BULLETIN

The American Society of Agricultural Engineers conducts an employment service especially for the benefit of its members. Only Society members in good standing may insert notices under "Positions Wanted," or apply for positions under "Positions Open." Both non-members and members seeking to fill positions, for which ASAE members are qualified, are privileged to insert notices under "Positions Open," and to be referred to members listed under "Positions Wanted." Any notice in this bulletin will be inserted once and will thereafter be discontinued, unless additional insertions are requested. There is no charge for notices published in this bulletin. Requests for insertions should be addressed to ASAE, St. Joseph, Michigan.

POSITIONS OPEN

WANTED IMMEDIATELY—College graduate with real mechanical aptitudes to serve as supervisor of industrial training in our American Agricultural and Industrial School in Liberia, West Africa. He must be able to handle maintenance and repairs of auto and gas engines and industrial equipment, also simple building construction, including plumbing and electric wiring. Because of the requirements of the Selective Service Act he must be able to secure exemption from this service or be beyond the ages included in it. He must have missionary motive and spirit and be able to work harmoniously with others, including those of the Negro race. Three-year contract. For particulars apply to Booker Washington Institute Trustees, Room 1410, 101 Park Avenue, New York City.

INSTRUCTOR wanted in farm shop and farm machinery, New York State Institute of Agriculture, Farmingdale, N. Y.

AGRICULTURAL ENGINEER wanted, preferably a young graduate with excellent scholarship and of the inventive type, and one who has had considerable training in electrical engineering, along with his agricultural engineering, and with a background of farming experience and interest in the improvement of farming equipment, to assist in a new project being set up by an agricultural engineering department of a state university in cooperation with a utility company to conduct a 2-year's study of the use of electric power in field operations. PO-127

ENGINEERING DRAFTSMEN. The U. S. Civil Service Commission announces an open competitive unassembled examination for five grades of engineering draftsmen, from assistant to chief (pay scale \$1620 to \$2600 per year), in optional branches including architectural, civil, electrical, heating and ventilating, lithographic, mechanical, plumbing, radio, structural, topographic and general drafting. The latter provides for assignment in any other branch except aeronautical, ordnance, or ship, for which separate examinations are now open. Applications will be rated as received and certification made as needs of the service require up to December 31, 1941, except that if sufficient eligibles are obtained, receipt of applications may be closed sooner upon due notice. Other usual Civil Service examination regulations apply.

TECHNOLOGISTS. The U. S. Civil Service Commission announces open competitive examinations for technologists in any specialized branch and in six grades from Junior (\$2000) to Principal (\$5,600). Examination for the junior grade is No. 29, assembled, and for the higher grades, No. 30, unassembled. Technology, within the meaning of the employment contemplated, is defined as "the necessary production, engineering, and scientific research work essential for the successful operation of an industrial plant, where such plant operation is based upon a thorough and expert knowledge of a branch of an applied science." Branches specifically mentioned include explosives, fuels, plastics, ceramics, minerals, paper, petroleum, rubber, and textiles. Applicants for the junior rating will also be certified for lower subprofessional ratings if desired. Duties are in the line of research, testing, design, development, and manufacture. Applications for No. 29 must be on file in Washington by February 20, or if from the far West, by February 24. Applications for No. 30 will be accepted until December 31, 1941, unless a sufficient number of applicants are certified before that time. Other usual Civil Service examination regulations apply.

TECHNICAL EDITORS. The U. S. Civil Service Commission announces open competitive unassembled examinations (No. 36) for assistant and associate technical editors for duty with the War Department, for general editorial work in the subject matter fields of engineering, chemistry, and physics. Applications must be on file in Washington by February 20, or if from the far West, by February 24. Other usual regulations apply.

POSITIONS WANTED

AGRICULTURAL ENGINEER with B. Sc. degree from University of Illinois, 1937, and three years' experience in rural electrification with a public utility in Central Illinois, desires similar position with a utility or REA having an aggressive rural electrification program. Present position has included experience in contacting farmers, securing right-of-way easements, preparing estimates, designing lines, and promoting the use of electricity. Age 26. Health excellent. No bad habits. Married. Rural background. PW-332